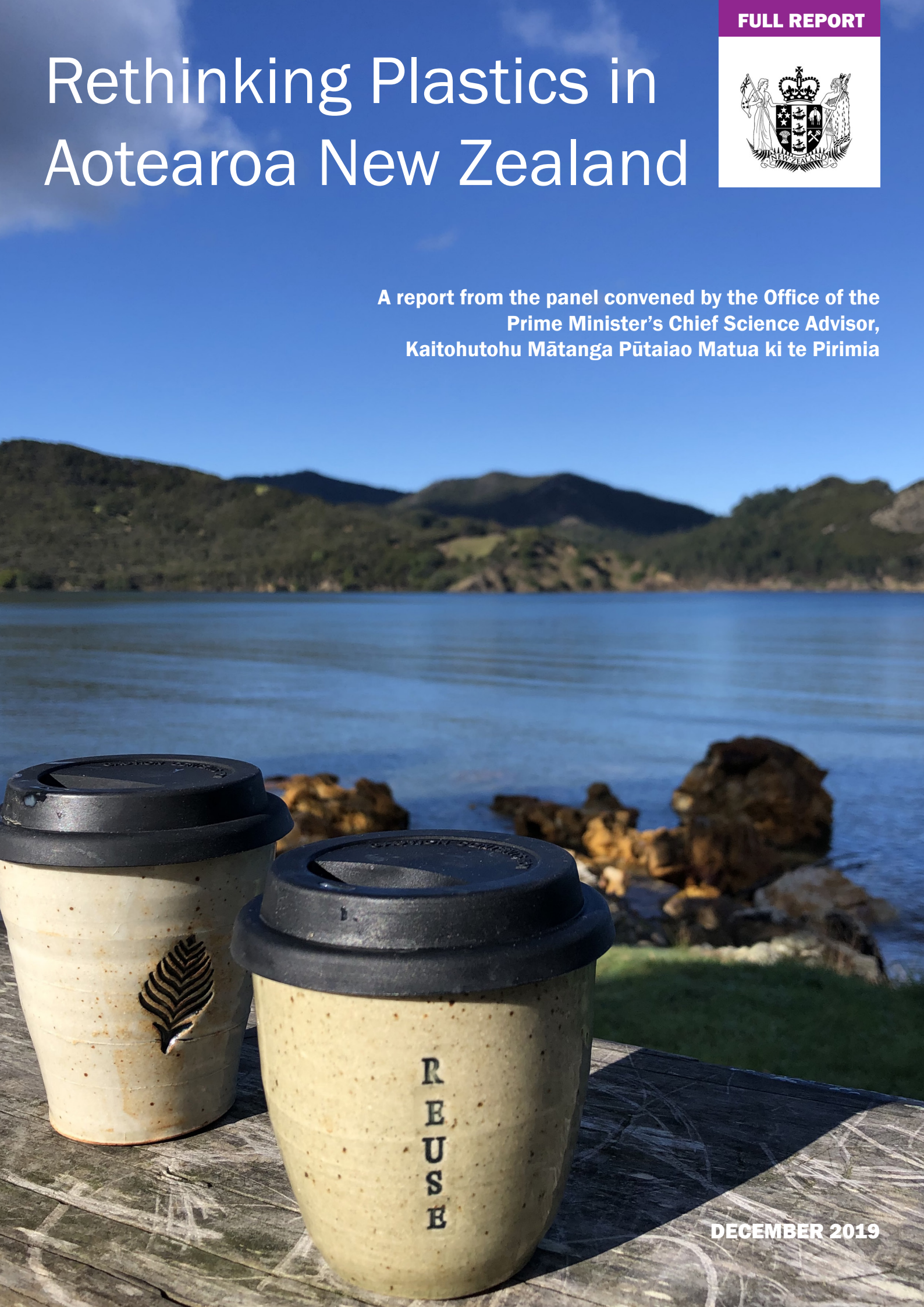
FULL REPORT

Rethinking Plastics in Aotearoa New Zealand

A report from the panel convened by the Office of the Prime Minister's Chief Science Advisor, Kaitohutohu Mātanga Pūtaiao Matua ki te Pirimia



DECEMBER 2019

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Office of the Prime Minister's Chief Science Advisor

The University of Auckland

Private Bag 92019

Victoria Street West

Auckland 1142

Aotearoa New Zealand

Phone 64 9 923 6318

Email info@pmcsa.ac.nz

Website pmcsa.ac.nz

Instagram @nz_chief_science_advisor

Twitter @ChiefSciAdvisor

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Office of the Prime Minister's Chief Science Advisor
Kaitohutohu Mātanga Pūtaiao Matua ki te Pirimia

Foreword

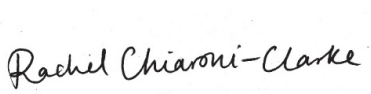
MAI I NGĀ MAUNGA KI NGĀ MOANA
MAI I UTA KI TAI
AHAKOA KI HEA I TE TAIAO
HE KIRIHOU, HE KIRIHOU, HE KIRIHOU![1]

Our panel set out with a bold and broad scope – to find ways to reduce the size of the plastic shadow that is cast by modern life. While we initially tried to reduce this scope, we ended up realising that plastic is everywhere and we must approach it from all angles simultaneously. Tackling the problem of plastic waste needs a systems change, a collection of adjustments – some large, some small – across all aspects of society. To begin, we painted ourselves a vision of what the future could look like if we make these changes. We present this vision first to set the stage for what follows.

This report is long, detailed and multifaceted, presenting the evidence-base, the gaps in information, and ideas to inspire change. A short summary report that captures the key messages from our work is also available from our website. Rethinking Plastics has received generous time and input from very many stakeholders, listed on the following pages. We set out to put together a report that included wisdom from within and way beyond the ivory tower, and are hugely grateful for the positive engagement which we have been privileged to receive from everyone we approached, or who came forward to support this kaupapa.

Much of our work was about seeking out and showcasing best practice and most of our recommendations can actually be captured in a single phrase: 'make best practice, standard practice'. We found this best practice and a host of new ideas across academia, research institutions, government, businesses, communities and individuals. Thank you for sharing your innovations and we hope you find it helpful to have them all in one place in this report and through our web portal (https://www.pmcsa.ac.nz/our-projects/plastics/), which connects to case studies to inspire, and much of our source material, and will continue to grow.

Ngā mihi nui



Dr Rachel Chiaroni-Clarke
Research Analyst and Writer
Office of the Prime Minister's Chief Science Advisor

Prof Juliet Gerrard FRSNZ, Hon FRSC
Prime Minister's Chief Science Advisor

On behalf of the #rethinkplastics panel, listed on page 13

[1] From the mountains to the oceans, from the land to the sea, everywhere in the environment, plastic can be found!

Our vision: Aotearoa in 2030 – imagining a different future

Bits of plastic still wash up on the beach – but they are fewer now, and no longer coming from our own drains and rivers. This isn't just an optimistic feeling we have, but a significant trend that we can clearly demonstrate using the rigorous methodology and the longitudinal citizen science data that started to be collected around all our shores in 2020. The data vacuum of the early 21st century started to fill at this point, and we began to see the difference we were making with our new policies and new habits. We also know what the plastics bits are made of, and there is more good news there too – more of the debris is able to be recycled, because there is infrastructure onshore to recycle it, so far less goes to landfill. We are using data collection methods that are compatible with those overseas, so we can tell that most places in Aotearoa have far less plastic than equivalent sites internationally. The Ellen MacArthur Foundation Award in 2026 for implementing our National Plastics Action Plan led to a boom in ecotourism at our cleanest beaches – and despite the spike in visitor numbers, they are still clean, with easy-to-use container deposit machines and recycling bins at hand. People are used to these bins, as the same ones are used all over the country and they have simple pictorial instructions enabling international visitors to quickly join in.

Ghost fishing has all but stopped in our waters, since the fisheries adopted new materials and new methods, inspired by commercial fisheries that shared their early innovations across the sector. Entangled gear is no longer discarded, and the ubiquitous blue rope that defined the age of plastic is still plentiful in the water, but the pieces are generally old and frayed, and there are fewer every year. Most of the debris on the shore is quickly collected and used for recycled 'beach plastic' containers, which are increasingly common as they offer a marketing advantage.

Pretty much everyone has their own keep-cups these days, and teenagers look at you funny if you don't have your own meal containers handy too. Aotearoa New Zealand was quick to see the market for stylish, non-leaking, all day kits that let you go about your day and enjoy take-away food without single-use plastic, and new businesses quickly grew up around this opportunity. We export these kits all over the world, with styles to suit all budgets. WINZ are a major customer and provide them for everyone on a benefit, with tips on how to use them to maximise healthy eating. The supermarkets expect customers to bring their bags and containers to collect fresh goods and refillery produce, and have their own brand versions available in store. Capitalising on the renewed interest in the 'Clean, Green New Zealand' brand, export earnings from these and similar products are booming.

Parcels now travel in reusable pods, a trend started by NZ Post in the early 2020s for domestic parcels. Consumers quickly embraced these handy pods, which keep mailed goods safe and don't create waste, and they swiftly became part of daily Kiwi life. Electric scooters and bikes have places to clip them for easy transport in urban settings. Led by innovative trade negotiations through the Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP), which examined international product stewardship schemes ahead of most countries, many of our trading partners accept our reusable pods too, so long as we take theirs in return. This was one of the ideas that inspired the World Trade Organisation (WTO) to find a new lease of life as the WSTO (World Sustainable Trade Organisation), ensuring that competitive advantages are not at the cost of environmental wellbeing.

Not everything can be reused yet of course, and landfills are still an important part of disposing of contaminated and dangerous waste. Following the landfill audit in 2020, the last of the old-style dumps closed three years ago, and all facilities are sealed, with leachate treated, microplastics trapped, and waste-to-energy schemes embedded in the infrastructure. The international award for the most environmentally friendly landfill received in Aotearoa in 2028 raised the profile of these facilities, which now have a small ecotourism component as people visit the regenerated native bush that grows around the methane pipes on closed landfills. The methane comes from food waste and composting bioplastics and fuels hundreds of thousands of homes, while preventing this potent greenhouse gas escaping to the atmosphere.

Essential single-use wrapping is partly replaced by fully compostable plastic made from waste biological sources. Following the early introduction of the compostable 'spife', more and more materials have been designed that provide

closed-loop use of plastic type materials, fully tested for both environmental and human health. The applications are still quite niche so far, and have yet to break into the medical space, but opportunities are growing as material scientists, engineers and cutting-edge businesses get more adept at and designing packaging that uses these cool new materials.

There is still some plastic waste, but the move to restrict to plastic types 1, 2 and 5 for clearly labelled packaging, restrict toxic additives, encourage use of one type of material not several, sort out the sorting, and stimulate entrepreneurial recyclers, has severely restricted the volume. Because companies are familiar with the waste hierarchy and often do a life cycle assessment (LCA) ahead of choosing packaging, it is unusual to find an item made solely of virgin fossil-fuel-based plastic. The container deposit scheme kicked this off back in 2020 – no clean, sorted bottle, no refund. Compact, efficient container deposit booths at the entrance of every supermarket are as busy as trolley bays, and issue customers with vouchers for their in-store purchases. This led to some new recycled material streams that regularly go into roads and building materials, following pioneering innovation in the late 2010s and some strict environmental testing. So effective are these processes, that some landfills are now being systematically mined for plastics to provide feedstock, strengthening the increasingly circular economy. The demand for electric vehicles is being matched by a steady increase in their reusable content. This is consistent with product stewardship requirements for not just plastics, but also batteries and tyres.

The plastic-eating enzymes and microbes are still being researched and the technology is at pilot scale, but still some way from commercial reality. The early work on enzymes that could degrade PET became less useful once all PET was being multiply recycled, but the work pivoted to focus on digesting the microplastics generated from car tyres and PVC – neither of which had been solved with redesign or engineering methods. The patent for one of these is held in Aotearoa New Zealand and there is some excitement that it may lead to major revenue streams soon. Updates from this research group have become one of the major highlights of the Biennial National Plastics Expo, which since its modest beginning in 2021 now attracts increasing international interest, with researchers, entrepreneurs and businesses attending from offshore by high-speed video-link, and sharing ideas globally. These and other plastic-substituting innovations, including our new generations of versatile sustainable bioplastic materials, drew widespread international interest at Aotearoa's Dubai 2020 Expo Pavilion, catalysing a world reputation for innovative materials and design, much as it did for merino wool clothing around the turn of the century.

Capturing momentum from the 2019 school strikes for climate, young people continue to push us to come up with better solutions. Our teachers are well supplied with resources to teach young people about plastics, thanks to universities offering sustainability courses in all degrees. School canteens are free of single-use plastics and universities have adopted best practice in their food outlets – with discounts when students bring their own containers, and only approved compostable containers for the forgetful. These are managed on site by commercial-scale composters. University students also started the 'say no to microfibre producing clothes' campaign in 2025, leading many manufacturers to change their materials and branding.

Aotearoa New Zealand has maintained and enhanced its global image as a set of beautiful islands with a pristine environment, enhanced by the blend of stewardship principles of kaitiakitanga and systems and design thinking. We have goal to be the first country to declare that it is no longer in the plastic age with a target date of 2050 – having reversed the environmental damage a century after the introduction of plastic as a revolutionary new material.

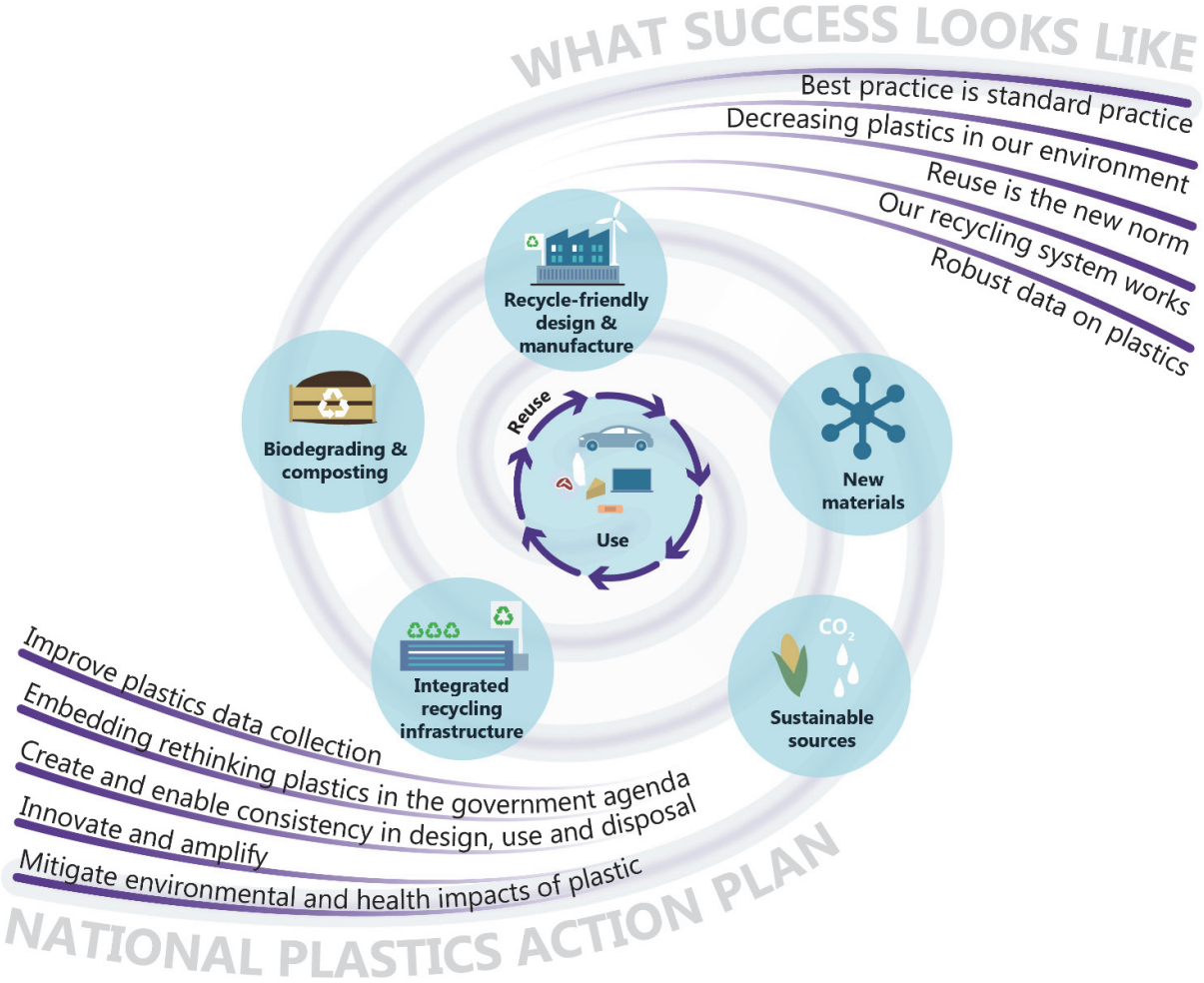


Figure 1 The Rethinking Plastics panel's vision for Aotearoa New Zealand

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Acknowledgements

Our panel

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- Dr Olga Pantos, ESR
- Abbie Reynolds, Sustainable Business Council
- Dr Diane Ruwhiu, University of Otago
- Professor Mark Staiger, University of Canterbury
- Professor James Wright, University of Auckland

Figure 2 The Rethinking Plastics Panel members and OPMCSA staff at the first panel meeting. From left to right: George Slim, Sarah McLaren, Bethanna Jackson, Olga Pantos, James Wright, Elspeth MacRae, Juliet Gerrard, Abbie Reynolds, Niki Harré, Mark Staiger, Diane Ruwhiu, Stephen Harris, Rachel Chiaroni-Clarke. Bottom right overlay: Melanie Mark-Shadbolt

Our reference group

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Abbreviations

Abbreviation	Definition
6Rs	Rethink, refuse, reduce, reuse, recycle and recover
AANZFTA	ASEAN-Australia-New Zealand free trade agreement
APCO	Australian Packaging Covenant Organisation
APEC	Asia Pacific Economic Cooperation
APR	Association of Plastic Recyclers
ARL	Australasian Recycling Label
ASEAN	Association of Southeast Asian Nations
ASTM	American Society for Testing and Materials
Bio-	Biological
BOP	Bay of Plenty
BPA	Bisphenol-A
BRANZ	Building Research Association of New Zealand
CCAMLR	Convention for the Conservation of Antarctic Marine Living Resources
CDS	Container Deposit Scheme (also referred to as Container Return Scheme)
CIEL	Center for International Environmental Law
CPTPP	Comprehensive and Progressive Agreement for Trans-Pacific Partnership
DCC	Dunedin City Council
DEFRA	Department for the Environment, Food and Rural Affairs (UK)
DoC	Department of Conservation
EAS	East Asia Summit
ECHA	European Chemical Agency
EDCs	Endocrine disrupting chemicals
EEZ	Exclusive Economic Zone
EMF	Ellen MacArthur Foundation
EPA	Environmental Protection Agency
EPS	Expanded polystyrene
ESR	Institute of Environmental Science and Research
EU	European Union
E-waste	Electrical waste
F.O.R.C.E.	For Our Real Clean Environment
FADs	Fish aggregating devices
FAO	Food and Agriculture Organisation
FMCG	Fast moving consumer goods
FTA	Free trade agreement
GDP	Gross domestic product
GDSN	Global data synchronisation network
GESAMP	Group of Experts on the Scientific Aspects of Marine Environmental Protection
GLAD	Global LCA Data Access network
H&S	Health and safety

HDPE	High-density polyethylene
ID	Identification
IOC	Intergovernmental Oceanographic Commission
IoT	Internet of Things
ISO	International Organization for Standardization
KDC	Kaipara District Council
KNZB	Keep New Zealand Beautiful
LCA	Life cycle assessment
LDPE	Low-density polyethylene
LGNZ	Local Government New Zealand
MARPOL	International Convention for the Prevention of Pollution from Ships
MBIE	Ministry of Business, Innovation and Employment
MFAT	Ministry for Foreign Affairs and Trade
MPI	Ministry for Primary Industries
MRF	Materials Recovery Facility
NCEA	National Certificate of Educational Achievement
NEMO	New End Market Opportunities
NFP	Not-for-profit organisation
NGO	Non-governmental organisation
NOAA	National Oceanic and Atmospheric Administration (US)
NPEGC	New Plastics Economy Global Commitment
NRRT	National Resource Recovery Taskforce
NSF	National Science Foundation (US)
NSW	New South Wales
NWDF	National Waste Data Framework
NZ	Aotearoa New Zealand
NZD	New Zealand Dollar
OECD	Organisation for Economic Cooperation and Development
OPMCSA	Office of the Prime Minister's Chief Science Advisor
OPRL	On-Pack Recycling Label (UK)
OWLS	Online waste levy system
PACER	Pacific Agreement on Closer Economic Relations
PCE	Parliamentary Commissioner for the Environment
PCR	Post-consumer recycled
PET	Polyethylene terephthalate
PGF	Provincial Growth Fund
PHA	Polyhydroxyalkanoates
PHB	Polyhydroxybutyrate
PLA	Polylactic acid
POPs	Persistent organic pollutants
PP	Polypropylene

PREP	Packaging Recyclability Valuation Portal
PS	Polystyrene
PSS	Product stewardship schemes
PU	Polyurethane
PURE	Plastic Use Resistance Education
PVC	Polyvinyl chloride
R&D	Research and development
R&I	Research and innovation
REBRI	Resource Efficiency in the Building and Related Industries
RECET	Resource Efficiency and Circular Economy Transition
RFP	Request for proposal
rPET	Recycled polyethylene terephthalate
SAPEA	Science Advice for Policy by European Academies
SBN	Sustainable Business Network
SDGs	Sustainable Development Goals
SMEs	Small to medium enterprises
SPREP	Secretariat of the Pacific Regional Environmental Programme
SPRFMO	South Pacific Regional Fisheries Management Organisation
SWAP	Solid Waste Analysis Protocol
UK	United Kingdom
UN	United Nations
UNEA	United Nations Environment Assembly
UNEP	United Nations Environment Programme
US	United States (of America)
WCPFC	Western and Central Pacific Fisheries Commission
WINZ	Work and Income New Zealand
WMA	Waste Minimisation Act (2008)
WMF	Waste Minimisation Fund
WMMP	Waste Management and Minimisation Plan
WRAP	Waste and Resources Action Programme
WTO	World Trade Organization

Recommendations

HE RANGI TĀ MATAWHĀITI
HE RANGI TĀ MATAWHĀNUI[2]

The recommendations that follow reflect the scale of the plastics problem that Aotearoa New Zealand currently faces. There is no silver bullet to fix this issue – we need to pull every lever. Rethinking plastics in Aotearoa New Zealand requires a bold and ambitious approach so that all New Zealanders can embrace kaitiakitanga. We envision a future of plastic use with updated systems, new materials, products and technologies that in combination enable citizens, businesses and communities to adopt more sustainable practices. Aotearoa New Zealand's journey to a circular economy for plastics needs to be based on short-and medium-term strategies, nested within a long-term vision.

Immediately – to stimulate change by 2021	Soon – to meet 2025 obligations	Later – to achieve zero plastic waste
1) IMPLEMENT A NATIONAL PLASTICS ACTION PLAN		
a) Building on actions outlined in this report *(including recommendations 2-6)* that outlines a clear vision and timeline of actions and signals expectations for the transition to a circular economy for plastics		
2) IMPROVE PLASTICS DATA COLLECTION		
a) Commission projects to audit and quantify known data gaps for plastics, including use, collection, reuse, recycling, disposal and leakage in NZ to fill *(align with 6a; supports 3h, 3i)* **b)** Support standardisation and national roll-out for citizen science litter monitoring projects, including kaupapa Māori projects *(align with 6a; connects with 5b; supports 3h, 3i)*, ensuring: i) Alignment with international best-practice methodologies ii) An open data policy, in line with the government-wide approach to increase openness and transparency **c)** Incentivise labelling of plastic type by manufacturers (resin ID code)	**d)** Mandate ongoing data collection at product level and establish an open data framework with a centralised database that includes measures for material type, weight, colour, recycled content, contamination, reuse, industry, source and end market (local or overseas), location, and average product lifetime of all plastic used in NZ *(partly implementable via 4b and/or 4c; prerequisite to 2e; supports 3h, 4i; supported by 6e)*	**e)** Review data policy settings of *2d* in light of technological developments and incorporate more difficult-to-acquire data in collection frameworks including, but not limited to, additives in plastic materials

[2] The person with a narrow vision sees a narrow horizon, the person with a wide vision sees a wide horizon

Immediately – to stimulate change by 2021	Soon – to meet 2025 obligations	Later – to achieve zero plastic waste
3) EMBED RETHINKING PLASTICS IN THE GOVERNMENT AGENDA		
a) Drive uptake of best-practice sustainable plastic use (e.g. reuse) through operational and funding levers: i) Adapt daily operations for government agencies and state-owned enterprises *(prerequisite to 3f)* ii) Make best practice a requirement of funding or approval (e.g. government-funded conferences) **b)** Undertake a scoping exercise to determine the best ways to connect internationally to drive alignment around sustainable materials and consistent product stewardship for plastics e.g. using New Zealand membership of international trade agreements such as the CPTPP, PACER Plus, Trans-Tasman agreements and AANZFTA (*supports 3g*) **c)** Adapt the Waste Minimisation Fund process to be more user-friendly and aligned to a national plastics action plan *(pending 4b)* **d)** Increase support for teachers to access resources where plastics is used as the context for teaching science, technology, social studies, sustainability and mātauranga Māori, and to utilise them in integrated, student-centred pedagogies **e)** Run national public awareness initiatives on plastic pollution, recycling and biodegradable or compostable plastics	**f)** Change government procurement to reflect sustainable use of plastic in all agencies and state-owned enterprises *(building on 3a; prerequisite to 3k)* **g)** Begin implementation of plastics action in international agreements *(based on findings from 3b)* **h)** Undertake analyses to model the economic, socioeconomic and environmental benefits of changing to more sustainable plastic use on different sectors *(supported by 2a, 2b, 2d; align with 4j)* e.g.: i) Fisheries ii) Aquaculture iii) Construction iv) Agriculture v) Exports vi) Tourism **i)** Incorporate indicators of plastic use, waste management and pollution, including a Tier 1 Indicator for litter, into existing national frameworks and processes *(supported by 2a and 2b)*: i) Environmental Reporting Programme ii) Indicators Aotearoa iii) Living Standards (wellbeing) Framework iv) Environmental-economic accounts v) Just Transitions initiatives	**j)** Ensure trade policy is kept up to date with evidence-based best practice on plastic import and export; advocate for international product stewardship principles **k)** Promote government-wide adoption of circular economy (*building on 3f*)

Immediately – to stimulate change by 2021	Soon – to meet 2025 obligations	Later – to achieve zero plastic waste
4) CREATE AND ENABLE CONSISTENCY IN DESIGN, USE AND DISPOSAL		
a) Co-design sector-specific best-practice guidance on plastic use to signal how to align to a future NZ plastics system, accounting for impacts of the Basel Convention amendment *(align with 4e, 4h, 4k)* **b)** Expand the waste levy to all landfill types and increase tonnage cost to discourage landfilling of recyclable waste plastic and the use of single-use plastics *(align with 2d; supports 3c)* **c)** Mandate product stewardship for priority products that contain plastic currently under consultation *(align with 2d; connects to 4e),* including: i) Packaging: include incentives to increase use of recycled plastic to strengthen markets for recycled plastic in NZ *(connects with 4d)* ii) Tyres: include approaches to reduce microplastics leakage *(align with 6d)* iii) Farm plastics iv) Agrichemicals v) E-waste **d)** Implement an industry-informed fit-for-purpose container deposit scheme (CDS) *(connects with 4c; supports 4f)*	**e)** Strategically invest in or incentivise development of systems and infrastructure to deal with our own plastic waste onshore, to support the best practice outlined in *4a* and new schemes developed through *4c*, including but not limited to: i) Onshore recycling of PET, HDPE, PP and possibly LDPE ii) Segregation of industrially compostable plastics **f)** Increase recycling rates and quality by: i) Improving source separation (e.g. at kerbside; store drop-off; community recycling centres; new tech; CDS), with H&S in mind (*connects with 4d*) ii) Standardising national recycling practice and ensuring equitable access iii) Implementing the Australasian Recycling Label (ARL) to make it easy for individuals to act **g)** Manage non-recyclable, non-compostable and non-biodegradable waste plastic in modern landfills *(coordinate with 6f)* **h)** Develop and implement biodegradable and compostable plastics standards (*align with 4a*) **i)** Facilitate access for organisations to life cycle assessment-based decision-support tools, supported by NZ-specific datasets *(supported by 2d)* **j)** Facilitate an active dialogue around rethinking plastics by setting targets and identifying opportunities to keep plastics in circulation or shift to more sustainable alternatives with individual sectors *(align with 3h; supports 4n)*, including: i) Fisheries ii) Construction iii) Agriculture iv) Textile and fashion retail v) Tourism	**k)** Use all regulatory and non-regulatory levers necessary to implement the best-practice expectations signalled in *4a* **l)** Monitor for innovative ways to manage plastic waste and scale-up infrastructure to reduce reliance on, or phase out use of, landfill for plastic waste *(including from 5a)* **m)** Develop and implement recycling standard(s) (*relates to 5e*) **n)** Evaluate sector progress and build on learnings to support development of other sector-specific action plans (e.g. healthcare, transport) *(learning from 4j)* **o)** Invest in equipment and technology to support the plastics manufacturing industry to manufacture bio-based plastics, including both biodegradable plastics and recyclable bio-based plastics at appropriate scale *(learning from 5a)*

Immediately – to stimulate change by 2021	Soon – to meet 2025 obligations	Later – to achieve zero plastic waste
5) INNOVATE AND AMPLIFY		
a) Attract research and innovation by offering a specific innovation fund to 'reimagine plastics' (*supports 4l, 4o, 5d, 5g*), focusing on the areas of: i) Infrastructure ii) Material science iii) Product design iv) Sustainability v) International connectivity Emphasising multidisciplinary approaches and drawing on areas such as: i) Mātauranga Māori ii) Engineering iii) Social sciences iv) Biophysical sciences v) Economics **b)** Share community initiatives and citizen science programmes and support their uptake in new contexts *(connects to 2b)* **c)** Build on successful innovative products and business models, e.g. those championed by the Sustainable Business Network	**d)** Make best practice standard practice by hosting expos (or a regional roadshow) to highlight and bring together innovative ideas from around the world related to plastics, including new technology, new materials, products, business models, design thinking, community initiatives and research, to drive further innovation and inspire others *(including those funded through 5a; supports 5f, 5g))* **e)** Ensure rigorous testing of new materials and products made from recycled plastic before application *(relates to 4m)*	**f)** Hold expo(s) every few years *(pending 5d)* **g)** Monitor projects, ensure 'fail-fast' culture, and scale-up successful ones *(based on 5a, 5d)*

Immediately – to stimulate change by 2021	Soon – to meet 2025 obligations	Later – to achieve zero plastic waste
6) MITIGATE ENVIRONMENTAL AND HEALTH IMPACTS OF PLASTIC		
a) Quantify environmental leakage of plastics, building on existing research *(connects with 2a, 2b; supports 6e)* **b)** Identify knowledge gaps and develop research agenda related to hazards, impacts and remediation of plastics, aligning to international conventions and pacts and connecting with international research efforts (*supports 6h*), with a particular focus on: i) Impacts on local communities, taonga species and sites of significance to mana whenua ii) Microplastics iiii) Environmental and food safety of recycled plastic and new materials iv) Developing methods for monitoring nanoplastics and potential toxic effects of plastics **c)** Develop and implement manufacturing and pre-production plastic pellet handling standards and regulations **d)** Commission a project to evaluate effectiveness, economics, and behavioural implications of different preventative measures for stopping macro and microplastic entering the environment to determine future efforts for NZ, e.g. public bins, washing machine filters, wastewater filtering processes, stormwater drain pipes, capturing at river mouth (*supports 6g*)	**e)** Working with mana whenua, roll out nationwide microplastic monitoring for marine, terrestrial and air environments, and wastewater and landfill leachate *(building on 6a; supports 2d)* **f)** Invest in prevention of landfill disasters, building on the national audit of at-risk landfills, to remediate issues or establish new facilities *(coordinate with 4g)* **g)** Invest in systems to prevent macro and microplastics entering the environment, take baseline data *(based on findings from 6d; supports 6l)* **h)** Support and regularly review local and international research into the environmental and health impacts of plastics, including those from *6b*, and ensure international connectivity (*supports 6j*) **i)** Identify areas where NZ development spending could help mitigate environmental and health impacts related to plastics, particularly for Pacific Island nations (*align with 6k*)	**j)** Support and regularly review long-term studies of environmental and health impacts of plastics *(building on 6h)* **k)** Support remediation efforts *(aligns with 6i)* **l)** Evaluate effectiveness of preventing environmental leakage, scale and adapt accordingly *(following from 6g)*

1. Motivation for rethinking plastics

MŌ TĀTOU, Ā, MŌ NGĀ URI Ā MURI AKE NEI[3]

In this introductory chapter, we outline the current state-of-play for plastics in Aotearoa New Zealand, highlight key work that we build upon, and describe the guiding frameworks for the Rethinking Plastics project.

[3] For us, and for those who follow

1.1 Plastic is a growing problem for Aotearoa New Zealand

Aotearoa New Zealand is at a pivotal point where we must rethink our relationship with plastics. Increasing public concern over the harmful effects of plastic pollution on our environment and health, and a growing appreciation of what we can learn from te ao Māori values such as kaitiakitanga (described in Section 1.3.1), make it an opportune time to initiate changes to mitigate the negative impacts of plastic while retaining its many benefits. We are in a unique position where we can weave our understanding of science, society and economics with mātauranga Māori to establish new practices that make a difference by reducing plastic pollution. Acting now is critical to preserve our natural environment for generations to come.

AOTEAROA NEW ZEALAND IS AT A PIVOTAL POINT WHERE WE MUST RETHINK OUR RELATIONSHIP WITH PLASTIC

The reason plastic has become so pervasive throughout our society is because it is a durable, flexible, inexpensive and lightweight material that meets the needs of a wide variety of applications. Rethinking plastics requires us to challenge the current ways we use and dispose of plastic to make these more sustainable and responsible. The most pressing challenges are to reduce the amount of virgin (new) plastic used, improve the effectiveness of approaches to keep the plastics used in circulation, and take national responsibility for our own plastic waste.

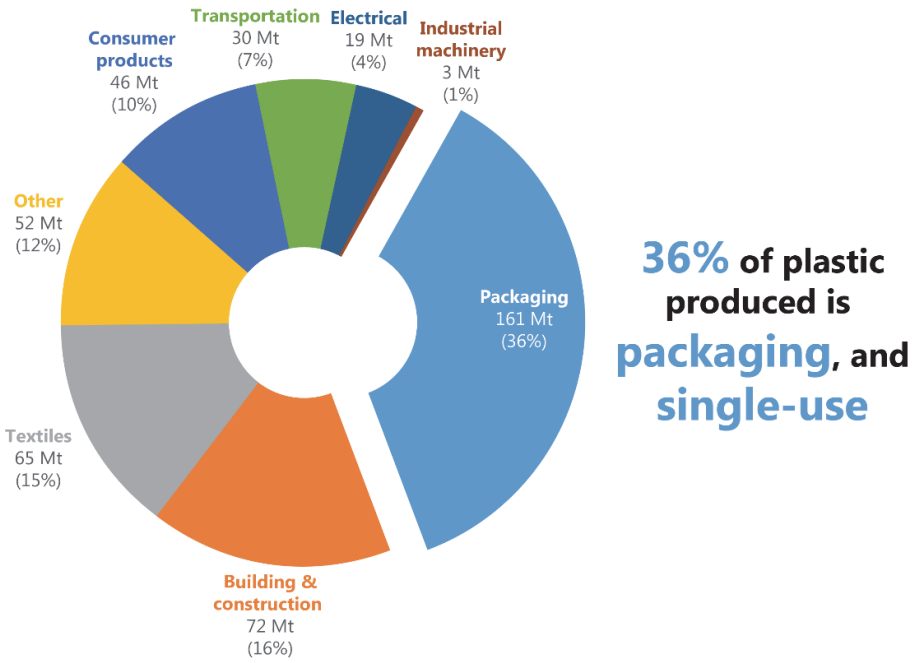


Figure 3 Global plastic production by industry. Mt: million metric tonnes. Source: Geyer et al. 2017

Since the 1950s, 8.3 billion tonnes of plastic has been produced globally and the majority of that (79%) has gone to landfill or been discarded into the environment.[4] It is difficult to comprehend the scale – but that's the same weight as 800,000 Eiffel Towers or over 1 billion elephants. Approximately 36% of that production has been for short-term or single-use plastics used for packaging that was most likely landfilled or incinerated, or leaked into the environment (see Figure 3).

The current way we source and use plastics is unsustainable. Global plastic production is projected to grow exponentially which will compound plastic pollution and our use of non-renewable resources (see Figure 4). Increasing plastic usage will also increase the global carbon footprint, with projections indicating that plastics will be responsible for up to 15% of the total 'carbon budget' by 2050 – more than air travel (currently around 2% of emissions).[5] Using less plastic and using

[4] Geyer et al., "Production, Use, and Fate of All Plastics Ever Made," *Science Advances* 3, no. 7 (2017)
[5] Center for International Environmental Law, "Plastic & Climate: The Hidden Costs of a Plastic Planet ", 2019; World Economic Forum, "The New Plastics Economy: Rethinking the Future of Plastics", 2016

renewable sources to make plastic will be important to prevent this projected increase in carbon footprint from plastics (discussed in Chapter 4).

PLASTIC PRODUCTION IS PROJECTED TO BE RESPONSIBLE FOR UP TO 15% OF THE TOTAL 'CARBON BUDGET' BY 2050

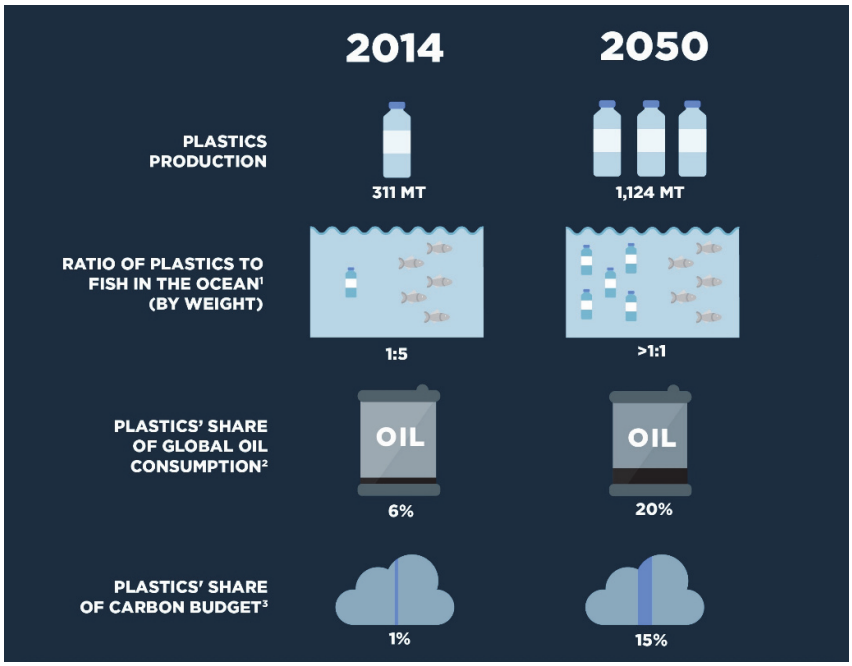


Figure 4 Forecasts of plastic use to 2050 if current consumption rates continue. Source: Ellen MacArthur Foundation

New Zealanders are contributing significantly to this global issue. According to the World Bank's 2018 global review of solid waste management, Aotearoa New Zealand is one of the most wasteful nations in the developed world, disposing of an estimated 159 grams of plastic waste per person each day, and ranked number 10 globally for municipal waste generation per capita.[6] Our waste per capita is well above the OECD average and is projected to remain so for the foreseeable future, unless significant changes are implemented.[7] Our small, dispersed population may contribute to these high rates of waste because it makes it more difficult to achieve economic onshore reprocessing, highlighting that localised solutions to rethinking plastics will be critical.

With increased knowledge and coverage of plastic polluting the environment, public concern about how we use and dispose of plastic has escalated. This has been accompanied by a willingness to take action to use plastics more sustainably and apply pressure to industry and government for change. Mounting public pressure has driven bans of single-use plastic items in many countries, which aims to decrease the overall amount of plastic use and pollution.[8] Consumer pressure has also prompted innovative businesses to evolve through product redesign, new materials and new business models. But people are limited by what's available to them. We urgently need new and improved systems to support people to use plastics more sustainably and responsibly. Establishing onshore reprocessing capabilities and a national recycling framework that is simple to use for individuals, communities and businesses is a critical early step. Rethinking plastics will be an ongoing process that requires continuous innovation and improvement with the expectation that best practice becomes standard practice.

RETHINKING PLASTICS WILL BE AN ONGOING PROCESS THAT REQUIRES CONTINUOUS INNOVATION AND IMPROVEMENT WITH THE EXPECTATION THAT BEST PRACTICE BECOMES STANDARD PRACTICE

[6] Kaza, "What a Waste 2.0 : A Global Snapshot of Solid Waste Management to 2050", 2018
[7] OECD, "Municipal Waste Database", 2015
[8] UNEP, "Single-Use Plastics: A Roadmap for Sustainability", 2018

1.1.1 An evidence-base is needed to drive policy

Aotearoa New Zealand can rethink how we use plastic, but the evidence-base to support these decisions in a system-wide way is lacking. In order to support evidence-informed decisions, this report collates and synthesises information and expert opinion to provide government with a rigorous system-wide overview of plastic in 2019, in the context of international best practice. The Office of the Prime Minister's Chief Science Advisor has worked in a transparent and inclusive way to bring together expertise from various sectors to inform this body of work. We present this information in a variety of accessible ways, including via our website at www.pmcsa.ac.nz/our-projects/plastics .To be of most benefit to the policy agenda and meet the timeframe of the Government's work programme to take action on Aotearoa New Zealand's waste – as announced by Associate Minister for the Environment, Eugenie Sage, on 19 August 2018 – we have endeavoured to provide this information and accompanying recommendations as we worked. [9] Where relevant, we have also considered how the available evidence and subsequent recommendations fit within the remit of existing legislation such as the Waste Minimisation Act 2008 (WMA), enabling a rapid pathway to improve our waste management and with immediate action. Other recommendations require more data gathering or research before they can lead to action.

AOTEAROA NEW ZEALAND CAN RETHINK HOW WE USE PLASTIC, BUT THE EVIDENCE BASE TO SUPPORT THESE DECISIONS IN A SYSTEM-WIDE WAY IS LACKING

This report aims to contribute to a society-wide change of heart and practice. Clear national goals, readily available information for shoppers and household use, aligned infrastructure and a few well-targeted rule changes could achieve significant, durable improvements while researchers and innovative businesses create new materials and business models. We seek to provide a trusted source of information for the public on the state of plastic use and a pathway forward for Aotearoa New Zealand. By engaging a wider audience, we hope to advance an inclusive and productive discussion of ways we can rethink plastics for the benefit of all New Zealanders.

Rethinking Plastics resources

A key issue met during preparation of this report is the lack of a central resource for information on plastics across the entire value chain, including the effects of plastic pollution. In response, we have developed a resource portal, available at www.pmcsa.ac.nz/our-projects/plastics/rethinkplastics-resources.

Figure 5 The Rethinking Plastics Resource Portal available at www.pmcsa.ac.nz/our-projects/plastics/rethinkplastics-resources

[9] Further details on the Government's work programme are available at: http://www.mfe.govt.nz/waste/what-government-doing

1.2 The current state of plastics in Aotearoa New Zealand

The level of public concern around plastic use and leakage into the environment is high. People are driving change through voicing concerns to business and government. In recent years, over 100,000 New Zealanders have signed petitions to the government to ban single-use plastic bags.[10] According to the 2018 Colmar Brunton Better Futures report published in February 2019, plastic is the number one concern for New Zealanders when it comes to sustainability, social and environmental issues.[11]

Aotearoa New Zealand has been slow to implement controls and is increasingly confronted with the consequences of other countries' actions. In 2017, this came into the spotlight when China – who had imported a cumulative 45% of the world's plastic waste since 1992 – instituted a new policy (China's National Sword) that significantly reduced their intake of plastic for recycling.[12] The effects of China's policy changes were felt more strongly in 2018, when restrictions were tightened further.

In response to the estimated 111 million tonnes of plastic waste that will be displaced by China's policy by 2030,[13] lower-income countries are becoming the dumping grounds for low-quality contaminated waste from higher-income countries such as Aotearoa New Zealand.[14] Legislation to ban imports of plastic waste and a consensus to amend the Basel Convention to place (further) controls on exports of difficult-to-recycle plastic waste (by requiring consent from Governments of receiving countries before shipping and to better regulate global trade[15]) will limit this practice, so the model of sending our plastic waste overseas is not sustainable. In the short-term this is causing issues around how we deal with plastic waste. Overall it has stimulated much-needed discussion around rethinking our use of plastic.

The New Zealand Government has recently taken steps to specifically address plastic pollution (see Table 2). The first was to prohibit the sale and manufacture of plastic microbeads in wash-off products such as cosmetics and cleaning products because of the known harms to human health and the environment. The regulation took effect on 7 June 2018. The second was to ban single-use plastic shopping bags with plastic handles, announced by the Associate Minister for the Environment, Hon Eugenie Sage, in August 2018, and implemented from 1 July 2019. More recently, the government announced consultation on product stewardship and plans to investigate the implementation of a beverage container return scheme (CRS).[16]

[10] Ministry for the Environment, "Proposed Mandatory Phase out of Single-Use Plastic Shopping Bags: Consulation Document", 2018
[11] Colmar Brunton, "Better Futures 2019", 2019
[12] Brooks et al., "The Chinese Import Ban and Its Impact on Global Plastic Waste Trade," *Science Advances* 4, no. 6 (2018)
[13] Brooks et al., "The Chinese Import Ban and Its Impact on Global Plastic Waste Trade,"
[14] McCullough, "Indonesia to Send Contaminated Recycling Back to Nz", *Radio New Zealand*, 20 September 2019
[15] Recent amendments to the Basel Convention place (further) controls on exports of difficult-to-recycle plastic waste, see: http://www.basel.int/.
[16] New Zealand Government, "Work Underway for Beverage Container Return Scheme", press release, 25 September 2019, http://www.scoop.co.nz/stories/PA1909/S00214/work-underway-for-beverage-container-return-scheme.htm

1.2.1 Aotearoa New Zealand has commitments to the global community

Plastic pollution is a global challenge that is being addressed at all levels – from local initiatives through to international agreements. Some countries and municipalities around the world are leading the way in developing local legislation and systems to transform plastic use, including the European Union (EU) and United Kingdom (UK). It is imperative we learn from those at the leading edge of the global shift in plastic use and disposal, so that we can adopt and adapt best practice models to Aotearoa New Zealand.

We are already engaged in a number of international organisations and initiatives that relate to rethinking plastics to support a global solution. Being part of international institutions tackling plastic use and pollution gives us the opportunity to share knowledge and combine efforts, particularly with regard to ocean plastics which are not bound by national borders – which is significant given we are an island nation. There are other multilateral coalitions to address plastics that Aotearoa New Zealand has not engaged in, such as a collaboration between the EU and Association of Southeast Asian Nations (ASEAN) nations to address issues around plastics.[17] In Table 1, we highlight some of the key international organisations and initiatives related to plastics. The list is not exhaustive, but gives an idea of the breadth and scope of the global appetite to challenge the way we currently use and dispose of plastic and shift to a more sustainable use of this material.

As well as drawing on international best practice and knowledge, we can share our learnings with the global community. Our responsibility to ensure the socio-environmental health of all our communities, including our Māori communities, means that we rely on the synergies of western and indigenous knowledge to inform practice. This basis for rethinking plastics can help guide international collaborative efforts, including prioritising learnings from other indigenous communities. We also have a responsibility to support nations in the South Pacific to manage plastics better. Pacific leaders describe plastics pollution as an environmental threat second only to climate change, and say they cannot mitigate its effects without mutual collaboration and help from developed countries. As a major supplier of imports by these countries, Aotearoa New Zealand can transfer improvements in the way we manage plastics and other waste onshore to these more vulnerable countries. This demonstration of partnership can include reducing the plastics content of goods and their packaging, but also supporting systems and consumption patterns that either demand less plastic or factor in its recovery or responsible disposal, as part of a more circular economy (see Section 1.3.2). The Ministry for Foreign Affairs and Trade (MFAT)'s Strategic Intentions includes reference to marine plastics in its aim to have better international stewardship of oceans, especially the Pacific and Southern Oceans.[18]

[17] EU and ASEAN commit towards a circular economy for plastics in the ASEAN region – details of collaboration, as established on 11 to 12 June 2019 in Kuala Lumpar, available at: https://asean.org/eu-asean-committed-towards-circular-economy-plastics-asean-region/
[18] Ministry of Foreign Affairs and Trade, "Strategic Intentions 2018-2022", 2018

Table 1 International organisations and initiatives related to plastics that are relevant to rethinking plastics in Aotearoa New Zealand

Organisation/initiative	How it relates to plastic
Alliance to End Plastic Waste	Pledge of US$1.5 billion by 30 multinational companies to 'get ahead of the curve' with plastics, anticipating that corporate social responsibility is hardwired into future notions of performance and success – and that customers will increasingly demand this and hold them accountable[19]
Asia Pacific Economic Cooperation (APEC)	Has developed marine debris management guidelines and other relevant working groups
Association of Southeast Asian Nations (ASEAN)	At their June 2019 Summit, the Leaders of the ASEAN issued the Bangkok Declaration on Combatting Marine Debris and the ASEAN Framework of Action on Marine Debris, which included considering establishing an ASEAN Center on Combatting Marine Debris[20]
Basel Convention	Recent amendments to the Basel Convention place (further) controls on exports of difficult-to-recycle plastic waste. The measures are due to commence in 2021[21]
Cooperation agreements	Depending on the country, can include plastic products and plastic waste in free trade agreements (FTA). Examples include references to plastics in trade agreements with China and the EU
Commonwealth Clean Oceans Alliance	Action group of the Commonwealth Blue Charter to tackle marine plastic pollution, with a NZ representative
East Asia Summit (EAS)	In November 2018, the East Asia Summit Leaders' Statement on Combating Marine Plastic Debris was announced, including NZ as a signatory[22]
Ellen MacArthur Foundation (EMF)	A UK-based organisation to accelerate the transformation to a circular economy, with an initial focus on plastics. They work with business, academia and governments to build a framework for an economy that is restorative and regenerative by design
European Commission	Published a European strategy for plastics in a circular economy in 2017 that laid out a series of actions the EU could take to reduce plastic waste. This has contributed to the EU leading the way in rethinking plastics[23]
G20 summit	Reduction of marine plastic trash was one of the major issues at the G20 summit of environment ministers in Japan in 2019. Ministers agreed to a deal to tackle marine plastic [24]
Global Ghost Gear Initiative	A cross-stakeholder alliance of fishing industry, private sector, corporates, NGOs, academia and governments focused on solving the problem of lost and abandoned fishing gear worldwide. NZ signed up to the Statement of Support in 2017[25]
Global Model for Near-Zero Ocean Plastic	A joint initiative between SYSTEMIQ, Common Seas and Pew Charitable Trusts to develop a global roadmap that identifies the steps needed to catalyse the necessary action and investment to reduce plastics entering the world's oceans. Common Seas are responsible for the policy analysis and SYSTEMIQ for the economic analysis

[19] More information available at: https://endplasticwaste.org/
[20] More information available at: https://asean.org/storage/2019/06/2.-Bangkok-Declaration-on-Combating-Marine-Debris-in-ASEAN-Region-FINAL.pdf and https://asean.org/storage/2019/06/3.-ASEAN-Framework-of-Action-on-Marine-Debris-FINAL.pdf
[21] See: http://www.basel.int/Pub
[22] More information available at: https://asean.org/storage/2018/11/EAS_Leaders_Statement_on_Combating_Marine_Plastic_Debris.pdf
[23] European Commission, "A European Strategy for Plastics in a Circular Economy", 2019
[24] Foster, "G20 to Tackle Ocean Plastic Waste as Petrochemical Producers Expand in Asia", *Reuters*, 13 June 2019
[25] More information available at: https://www.ghostgear.org/

Organisation/initiative	How it relates to plastic
Global Partnership on Marine Litter	A multi-stakeholder partnership that provides a unique mechanism to bring together all actors working on marine litter to share knowledge and experience and to advance solutions to this pressing global issue. It is in response to the need to meet SDG 14.1 and is connected to the UNEP[26]
Global Plastics Alliance (part of the Global Business Alliance for the Environment)	Plastics associations around the world signed the Declaration of the Global Plastics Associations for Solutions on Marine Litter in 2011. Plastics NZ is a signatory to this commitment and are the local stewards of Operation Clean Sweep® (see Case Study 2.4.11)
High Level Panel for a Sustainable Ocean Economy	An initiative of serving heads of government that aims to produce a report and suite of bold but pragmatic recommendations that are a roadmap for aligning robust economic development with protecting the natural capital of the ocean. NZ is not a member of the panel but has engaged through an Australian representative[27]
International Maritime Organisation (IMO) Marine Environment Protection Committee	Committee of the IMO that discusses what the appropriate measures are for some key classes of plastic pollution, in particular lost fishing gear, and who developed an action plan to address marine plastic litter from ships.[28] NZ is a member
Organisation for Economic Cooperation and Development (OECD)	Collates data to compare OECD nations, including municipal waste data, and publishes reports such as 'Improving Plastics Management: Trends, policy responses, and the role of international co-operation and trade'[29]
Secretariat of the Pacific Regional Environmental Programme (SPREP)	Focuses on ocean ecosystems, waste management and pollution control[30]
United Nations Environment Programme (UNEP)	Responsible for the publication of several key reports, including 'Single-use plastics: A roadmap for sustainability' and 'Mapping of global plastics value chain and plastics losses to the environment, with a particular focus on the marine environment'[31] Established the Clean Seas campaign, which aims to engage governments, the general public and the private sector in the fight against marine plastic pollution. Started in 2017 for 5 years[32] Initiated a resolution on marine plastic litter and microplastics that includes recommendations for member states related to marine plastic pollution[33]

[26] More information available at: https://gpmarinelitter.org/
[27] More information available at: https://www.oceanpanel.org/
[28] More information available at: http://www.imo.org/en/MediaCentre/MeetingSummaries/MEPC/Pages/Default.aspx
[29] OECD, "Improving Plastics Management," (2018) The report provides an overview of current plastics production and use, the environmental impacts that this is generating and identifies the reasons for currently low plastics recycling rates, as well as what can be done about it.
[30] More information available at: https://www.sprep.org/
[31] Single-use plastics: A roadmap for sustainability looks at what governments, businesses and individuals have achieved at national and sub-national levels to curb the consumption of single-use plastic; and Mapping of global plastics value chain and plastics losses to the environment provides a comprehensive overview of the global production and consumption of different polymers. Based on available literature on the losses of plastics throughout the plastic value chain, it estimates the annual mass of microplastics and macroplastics that are being lost to the environment.
[32] More information available at: https://www.cleanseas.org/
[33] United Nations Environment Assembly of the United Nations Environment Programme Fourth session, Nairobi, 11-15 March 2019, Resolution 6: 'Marine Plastic Litter and Microplastics', see: http://web.unep.org/environmentassembly/ministerial-declaration-resolutions-and-decisions-unea-4

Organisation/initiative	How it relates to plastic
United Nations UN Sustainable Development Goals (SDGs)[34]	Several goals are pertinent to the issue of tackling plastic waste in NZ and connect our work with a broader effort to achieve a better and more sustainable future for all. NZ has committed to the implementation of the 2030 Agenda for Sustainable Development and achievement of the 17 SDGs. In 2019, MFAT undertook NZ's first voluntary SDG review[35] (see Appendix 1 for targets related to plastics and NZ's review against these)
World Economic Forum	Running a Global Plastic Action Partnership which aims to translate political commitments to address plastic pollution into action by fast-tracking circular economy solutions in coastal countries battling plastic waste[36]
WRAP (Waste and Resources Action Programme)	UK organisation that works with governments, businesses and communities to deliver practical solutions to improve resource efficiency. Responsible for the UK Plastics Pact, including a roadmap to 2025. WRAP has a global division set up to support other countries[37]

[34] UN General Assembly, "Transforming Our World: The 2030 Agenda for Sustainable Development September 25, 2015", 2016
[35] Ministry of Foreign Affairs and Trade, "He Waka Eke Noa: Towards a Better Future, Together. New Zealand's Progress Towards the Sdgs - 2019", 2019
[36] More information available at: http://www3.weforum.org/docs/WEF_FOA_GPAP.pdf
[37] More information and relevant publications are available at: http://www.wrap.org.uk/category/materials-and-products/plastics

1.2.2 A coordinated approach is needed

The need for urgent action on plastics in Aotearoa New Zealand has led to several industry, community and academic groups undertaking work to address specific aspects of plastics (discussed in detail in Chapter 2). Some of the deeper dives into the issue are available through our plastics resource page and include:

- **The Sustainable Business Network –** New Zealand's plastic packaging system: an initial circular economy diagnosis (2018): A report that outlined the priorities and actions needed to make Aotearoa New Zealand's plastic packaging system more sustainable, highlighting the need to think more broadly than recycling and consider product redesign and new business models, with the need for incentives and infrastructure development.[38]
- **The Parliamentary Commissioner for the Environment –** Biodegradable and compostable plastics in the environment: a comprehensive resource developed in response to the confusion surrounding degradable plastic, presented as Q&As.[39]
- **The Aotearoa Circle:** A voluntary initiative that brings leaders from the public and private sectors together to amplify existing efforts and focus on priority areas related to sustainability and responsibility for our natural resources.[40]
- **The National Resource Recovery Taskforce (2019):** In response to changes in recycling markets due to China's National Sword policy, a taskforce was established to provide a situational analysis of Aotearoa New Zealand's resource recovery industry and provide recommendations for government on ways to support and stabilise the industry.[41]
- **The Royal Society Te Apārangi –** Plastics in the Environment: Te Ao Hurihuri – The Changing World (2019): A report summarising how plastics enter the environment and the risks plastics pose to wildlife and humans.[42]
- **The Government Procurement Rules:** The fourth edition of the New Zealand Government Procurement, which came into force on 1 October 2019. Rule 20 is 'supporting the transition to a low emissions economy and designing waste out of the system'.[43]
- **Roadmap for New Zealand's New Plastics Economy:** Scion is partnering with Plastics NZ, Packaging NZ and the Sustainable Business Network to develop a roadmap for New Zealand's Plastics Economy (currently underway).[44]

Our report builds on and integrates these key bodies of work as part of a system-wide overview. With the growing need for action in this space, it is important that different workstreams are shared and coordinated where appropriate. This will help harness shared ambition and accelerate the transition to a more circular economy for plastics.

1.2.3 With challenges come opportunities

Our most significant risks associated with plastic, including climate change, environmental consequences, health impacts and economic implications are shared globally. These are discussed throughout the report. We also face unique challenges and responsibilities when it comes to plastic use and waste, each presenting both barriers and opportunities.

Because we are a geographically isolated nation, international solutions to deal with waste may not always be easily translatable to our situation. On the other hand, isolation enables us to control our borders in ways that could assist a genuinely circular approach to managing our own waste. Such an approach would be in line with our responsibility to act as guardians of the environment through kaitiakitanga (discussed in Section 1.3.1).

Our economy is heavily reliant on our primary products export industry, which itself relies on packaging that is hygienic, resilient and lightweight to transport perishable food, beverages and their ingredients around the world. Plastic meets

[38] Circular Economy Accelerator Sustainable Business Network, "New Zealand's Plastic Packaging System, an Initial Circular Economy Diagnosis", 2018
[39] Parliamentary Commissioner for the Environment, "Biodegradable and Compostable Plastics in the Environment", 2018
[40] For more information about The Aotearoa Circle see: https://www.theaotearoacircle.nz/
[41] Eunomia Research & Consulting Ltd, "National Resource Recovery Project – Situational Analysis Report", 2018
[42] Royal Society Te Apārangi, "Plastics in the Environment: Te Ao Hurihuri – the Changing World", 2019
[43] New Zealand Government Procurement Branch, "Government Procurement Rules: Rules for Sustainable and Inclusive Procurement", 2019
[44] Scion, "Plastics Nz Awards and Launch of Plastics Roadmap", press release, 20 May 2019, 2019, https://www.scionresearch.com/about-us/news-and-events/news/2019/plastics-nz-awards-and-launch-of-plastics-roadmap

all three criteria and is favoured by our export industry, so as a nation we are responsible and rely on sending thousands of tonnes of plastic overseas every year. Our economy is also strong enough that locally we have the opportunity to buy discerningly, incentivise selectively to achieve targeted outcomes, and to invest in infrastructure and research into new, more sustainable packaging materials.

Lastly, our population size and spread also creates challenges and opportunities around plastic. Relative to the global market, we are small – so it may be more challenging to demand changes to plastic used by multinational companies. However, we can create local solutions. We have adequate infrastructure, social and economic connectivity to be able to design systems that work for us, and inspire others. New Zealanders are agile and adaptable with a mind-set that enables us to be innovative in the face of new challenges. In particular, having Māori scientists and innovators who draw on traditional wisdoms and values that embody te ao Māori to solve local and global challenges gives us an edge.

To address these challenges and rise to the opportunities, we need to simultaneously remediate plastic pollution issues and establish sustainable practices for plastic use.

1.2.4 There is confusion around how plastics are made and classified

Plastic can be identified by the type of plastic (defined by its physical properties or chemical composition), the source of the material from which plastic is made (biological sources vs fossil fuels) and/or how the plastic can break down (degraded by microbes or not, and whether this is at a standard rate or faster due to chemical additives). Plastic can also be identified by whether it is made with new (virgin) or recycled content.

Physical properties

Plastics are either defined as thermoplastic or thermoset. The key difference between these classes is how the plastic responds to heat. Like chocolate, thermoplastic polymers can be reheated and moulded with no or minimal change to their chemical or physical properties. A level of degradation occurs with each cycle and depends on the type of thermoplastic. In contrast, thermoset plastics cannot be reshaped or recycled once they have been moulded or hardened – like an egg. This feature helps thermoset plastics withstand higher temperatures and chemical attack without loss of structural integrity. These different properties lend thermoplastics and thermosets to different applications.

When a type of plastic is referred to as a ‘thermoplastic’ or ‘thermoset’ we are defining it based on its physical properties.

Chemical composition or resin type

This tells you what the plastic is made from – i.e. the chemical substance used as the basis of a plastic product. Each resin type has different chemical properties that meet the requirements for specific types of packaging or products. It is standard practice to code plastic products by their resin type. The ASTM International standard ASTM D7611/D7611M is widely accepted as the global identification system.[45]The resin identification tells people what the plastic is made from, but not whether it can or will be recycled. Whether a product is actually recycled can depend not just on the type of plastic, but also on the other materials, colour and additives included in the composition. These are not captured by the code. Sometimes multiple plastics are used in an item which makes it significantly more difficult, or impossible, to recycle those materials.

When a plastic is referred to as ‘PET (#1)’ or ‘HDPE (#2)’ we are defining it by its resin type (chemical make-up).

[45] ASTM International, "Astm D7611/D7611m-18 Standard Practice for Coding Plastic Manufactured Articles for Resin Identification", 2018

Feedstock

Plastic can be made from different raw materials known as feedstock. The vast majority of plastic raw material comes from fossil fuel. The remaining plastic is made from renewable biologically produced compounds such as corn starch and sugarcane.

- Fossil-fuel-based: Plastics derived from petroleum by-products or natural gas, a non-renewable source.
- Bio-based: Plastics derived from biomass sources, which are renewable. For a plastic to be classified as bio-based, the source material is not necessarily 100% biomass. Bioplastic (as used in this report) refers to bio-based plastics, but is sometimes incorrectly used to refer to biodegradable plastics. Not all plastic made from bio-based materials is biodegradable. The relationship between these two properties is explained in Figure 6.

Some bio-based plastics are identical in chemical composition to their fossil-fuel-based counterparts, but not all are.

When a plastic is referred to as bio-based, we are defining it based on what it is made out of.

Additives

Both bio- and fossil-fuel-based plastics can have additives included in their composition. The European Chemicals Agency (ECHA) has worked with industry to map out the range of over 400 functional additives or pigments currently used in plastic production.[46] These are used to enhance product performance or aesthetics. A discussion around the impacts and risks associated with chemical additives on the environment follow in Section 4.14.

When a plastic is referred to as oxo-degradable, we are defining it based on certain chemical additives that have been added to the material.

Degradation

All plastic will break down eventually, but it may take thousands of years. How it will break down and how long it will take depends on the chemical properties and disposal conditions (see Figure 6). Fossil-fuel-based plastics were traditionally non-biodegradable – the polymers that make up the plastic cannot be degraded by living organisms (microbes), but they gradually break down due to the effects of sunlight, heat and friction. Non-biodegradable plastic fragments into microplastics and is likely to take centuries to break down completely.

Biodegradable plastics are an alternative type of plastic that can be degraded by microbes into simple chemical elements – ultimately CO_2, methane and water. Disposal conditions dictate whether biodegradable plastic actually breaks down into these elements. In the right environment (usually commercial composting facilities) the plastic can be biodegraded and fully break down. In the wrong environment (i.e. the ocean), biodegradable plastic acts like non-biodegradable plastic and breaks down to microplastics.

A subset of biodegradable plastics are compostable. The polymers that make up compostable plastic can be broken down by microbes in a composting environment and fully return to nature. Most compostable plastics won't do this in a home composting bin, only in a commercial-standard compost with specific conditions. Like all biodegradable plastics, compostable plastics are not necessarily bio- based and the disposal conditions dictate how they actually break down. Another subset of biodegradable plastics are in development that will be able to degrade in the marine environment. This is significant as the marine environment is the 'sink' for a significant amount of plastic waste.

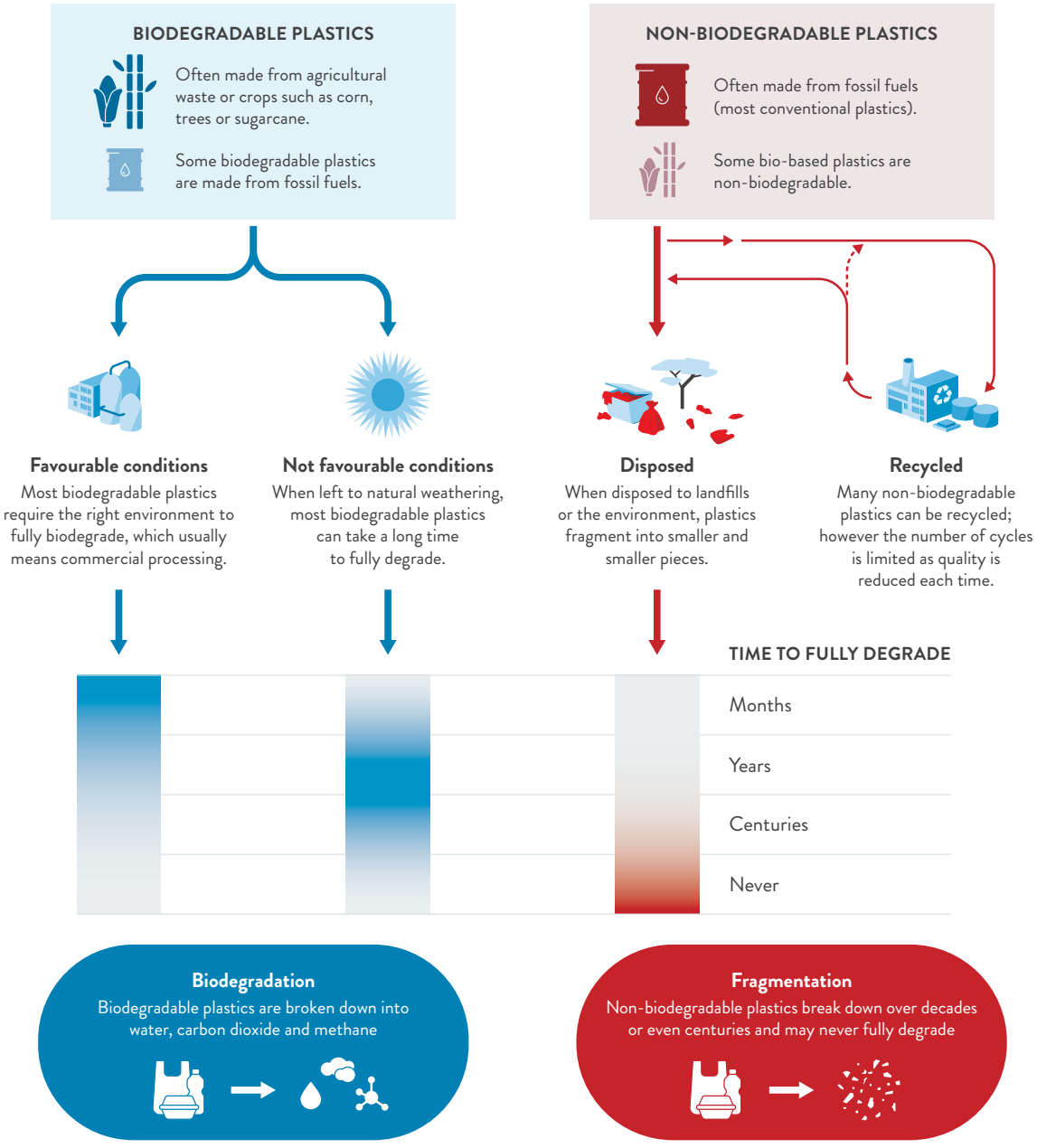
When a plastic is referred to as biodegradable, compostable or non-biodegradable, we are defining it based on how it will break down.

Figure 6 (opposite) Relationship between the source of plastic and how it degrades. Credit: royalsociety.org.nz/plastics licenced under CC BY 3.0 NZ

[46] European Chemicals Agency, https://echa.europa.eu/mapping-exercise-plastic-additives-initiative

PLASTIC TYPES, BIODEGRADATION AND FRAGMENTATION

The chemical structure of the plastic, not whether it was sourced from renewable or non-renewable resources, determines whether a plastic is biodegradable.



1.3 Guiding frameworks

1.3.1 Te ao Māori

Embracing the wisdom of te ao Māori, which addresses complex issues in a holistic way, we have used an overarching framework to guide our work on rethinking plastics in Aotearoa New Zealand. Reverend Māori Marsden (2003) described the Māori world view as a complex and interconnecting value system that honours the Māori relationship with the natural environment as a fundamental aspect of Māori cultural identity – linking lands, waters and peoples in a whole-of-landscape approach, encapsulated in the phrase 'ki uta ki tai' (from the mountains to the sea).[47] A Māori worldview acknowledges the relationship between people, landscapes, waterways and oceans, which is pertinent in rethinking plastics in Aotearoa New Zealand.

Te ao Māori emphasises the connection between people and the natural environment – a connection that has arisen from the strong sense of unity with, and enduring relationship within, defined territories, land and the natural world.[48] These relationships are threatened by the plastic maunga (mountain) resulting from our reliance on and ill-considered use of plastics. The Māori worldview recognises the building of mauri (life and wellbeing sustaining capacity) within and between the natural environment and society.[49]

Mātauranga Māori, or Māori epistemology, is at the heart of te ao Māori and is described as a complex system of knowledge created by Māori according to a set of key ideas that explain the human experience of the world.[50] Representing a uniquely Māori understanding of the world around us, mātauranga provides insight into understanding the existence of, and relationship between, all animate and inanimate things.[51] Such a dynamic and inter-connected perspective locates Māori knowledge and ways of knowing within the domain of 'systems thinking', which places greater emphasis on understanding the relationships between the components of a system. It is the pattern of these relationships that determines the characteristics and properties of system behaviour. In this way it aligns very well with modern Western thinking in sustainability. Through centuries of observation and interaction, Māori have developed a deep understanding of the natural environment. Māori knowledge and the systems thinking approach can help shape our response to the environmental impacts of plastic.

Through mātauranga Māori, cultural values such as kaitiakitanga (the responsibility to secure natural resources for the benefit of all – not just for present generations but for those to come), kotahitanga (the acknowledgement of unity and collective action), whanaungatanga (recognising the intergenerational nature of the relationships between people and the natural world) and wairuatanga (recognising spirituality) are enacted, ensuring 'the mauri of both human and non-human people are more likely to be maintained and, in turn, the life-generating capacities of these entities ensured'.[52]

> "The Māori world view acknowledges a natural order to the universe, a balance or equilibrium, and that when part of this system shifts, the entire system is put out of balance. The diversity of life is embellished in this world view through the interrelationship of all living things as dependent on each other, and Māori seek to understand the total system and not just parts of it."
>
> Harmsworth and Awatere, 2013[53]

These values and connections can guide more responsible management of plastic throughout its life cycle.

[47] Hutchings, "Enhancing Māori Agribusiness through Kaitiakitanga Tools", 2017
[48] Durie, "Measuring Māori Wellbeing", 2006
[49] Reid, "Indigenous Sustainability Indicators for Māori Farming and Fishing Enterprises. A Theoretical Framework.", 2013
[50] Royal, "Mātauranga Māori: Paradigms and Politics. A Paper Presented to the Ministry for Research, Science and Technology. ", 1998
[51] Hutchings, "Enhancing Māori Agribusiness through Kaitiakitanga Tools", 2017
[52] Reid, "Indigenous Sustainability Indicators for Māori Farming and Fishing Enterprises. A Theoretical Framework.", 2013
[53] Harmsworth et al., "Indigenous Maori Knowledge and Perspectives of Ecosystems," *Ecosystem Services in New Zealand: Conditions and Trends* (2013)

Kaitiakitanga is a particularly significant value to guide how we rethink plastics. This traditional concept is about safeguarding the future by preserving intrinsic value (i.e. not being wasteful) and retaining options we might not yet know exist. The practice of kaitiakitanga allows Māori and non-Māori alike to reflect on the notion of kinship with nature, and how this idea might be useful in an environmentally threatened world. Kaitiakitanga is being discovered and explored by non-Māori, and its importance is increasingly recognised by New Zealanders as a guiding principle to safeguard our environment. It is our local embodiment of a global shift towards sustainability. When guided by a Māori world view and values, we are obliged to act as guardians of the environment in Aotearoa New Zealand.

Rethinking plastics presents an opportunity to embrace kaitiakitanga in a contemporary setting, as a guiding principle. We use kaitiakitanga as a tool and a process to inform our recommendations around protecting the environment. While short-term fixes are necessary to abate the current damage inflicted on the environment by plastic, we are also focused on our obligation under kaitiakitanga to sustain the environment's capacity to support life for present and future generations – our mokopunas' mokopuna (grandchildrens' grandchildren). The concept of stewardship aligns well with circular economy solutions and inspires innovation.

RETHINKING PLASTICS PRESENTS AN OPPORTUNITY TO EMBRACE KAITIAKITANGA IN A CONTEMPORARY SETTING, AS A GUIDING PRINCIPLE

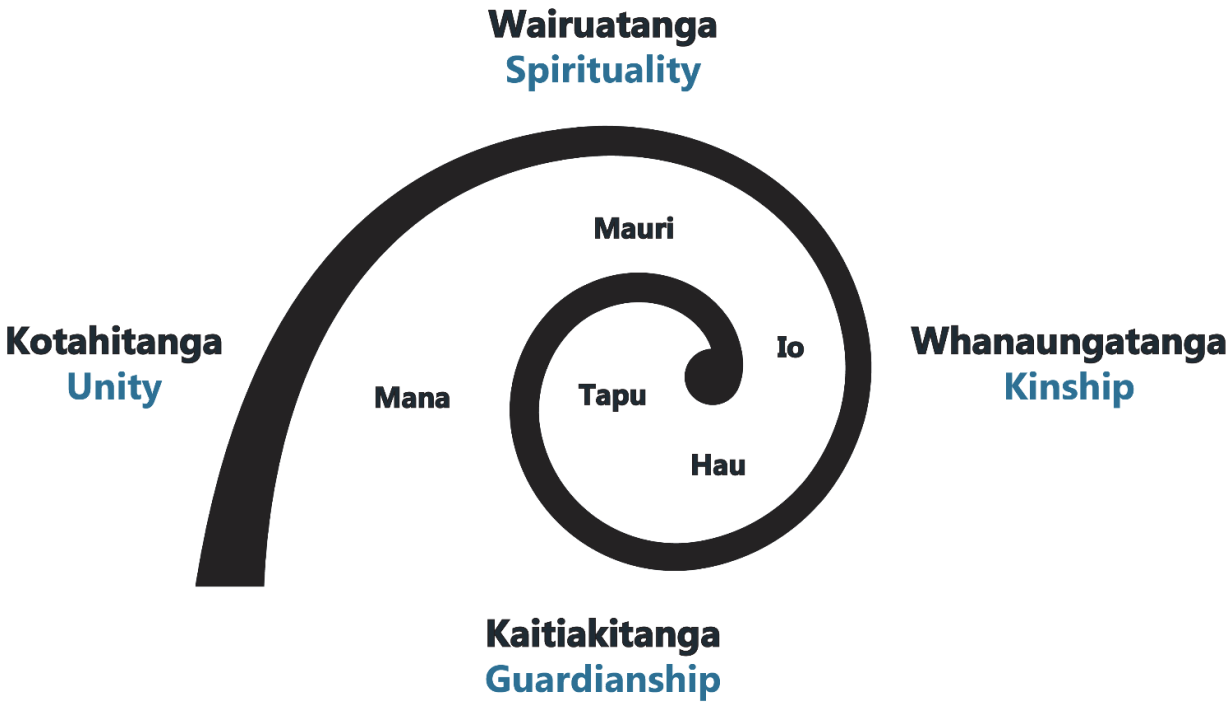


Figure 7 The Koru of Māori ethics developed by Manuka Henare in 1998. The core Māori values of Mana, Mauri, Tapu, Io and Hau are depicted in the centre of the koru as the founding values that inform the ethical concepts and practices of Kotahitanga, Wairuatanga, Whanaungatanga and Kaitiakitanga

1.3.2 Circular economy

Plastic pollution is an environmental symptom of our 'throw away' society. Globally, there is an increasing call to use whole-of-life accounting – that is, to broaden how we cost and value resources so that we also account for costs that are usually overlooked such as environmental and social aspects (e.g. Kate Raworth's concept of Doughnut Economics).[54]

This thinking is particularly pertinent to plastics as currently the cost of plastic is modelled on the resource input and manufacturing costs, but ignores the costs of disposal and environmental leakage – which have proven to be significant. The costs associated with the full life cycle of a product are met elsewhere in the economy.

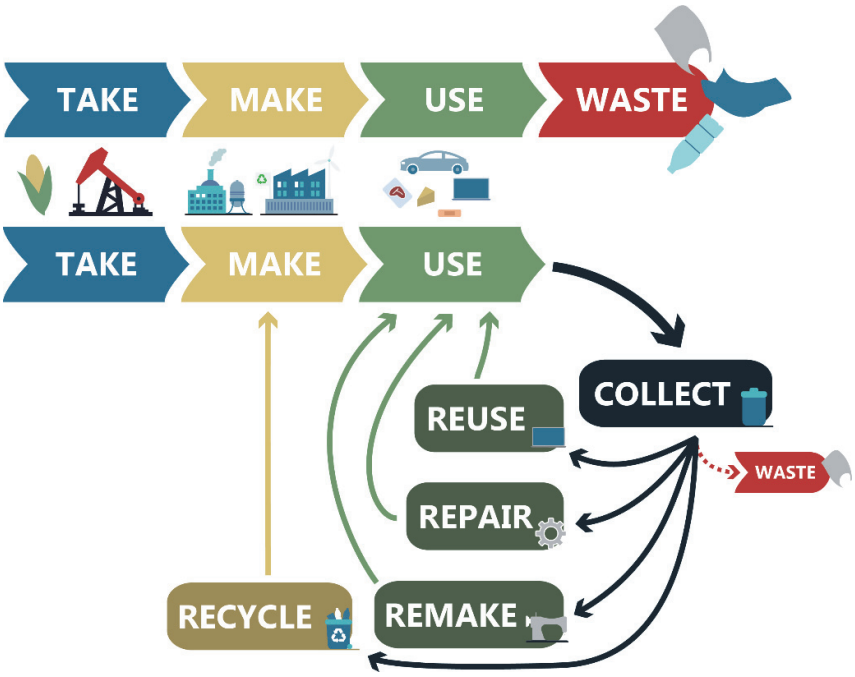


Figure 8 Reuse, repair, remaking and recycling can support the transition from a linear to circular economy for plastics

Fundamental to these changing values is recognising that virgin feedstock for fossil-fuel based plastic is a finite resource with competing uses, so we need to make smart choices about how we use this material and, more importantly, keep it in use. Internationally, countries ranging from the wealthiest in the OECD to some of the world's least developed agree that a new relationship with plastic is urgently needed in order to retain its many benefits, yet incentivise responsible use and disposal. Some of this rethinking is being grouped under the loose label of 'circular economy' – in which the design, value-retention, reuse and consideration of alternatives to plastics are weighed in an integrated economic, social, cultural and environmental framework.

Aotearoa New Zealand has started to embrace elements of a circular economy. The New Zealand Plastic Packaging Declaration of June 2018 was a pledge by 12 multinational and several local businesses to use 100% reusable, recyclable or compostable packaging in New Zealand operations by 2025. In August 2018, the New Zealand Government announced a work programme to take action on waste, signalling the government's initial commitment to transitioning to a circular economy approach. Roughly two months later, on 29 October 2018, the New Zealand Government signed the New Plastics Economy Global Commitment led by the Ellen MacArthur Foundation in collaboration with the UNEP.[55] By signing this international declaration, the government agreed to meet stringent targets, including the commitment made by signatories of the New Zealand Plastic Packaging Declaration to ensure that 100% of plastic packaging can be easily and safely reused, recycled or composted by 2025. This report provides an evidence-base to guide this change.

[54] Raworth, *Doughnut Economics: Seven Ways to Think Like a 21st Century Economist* (Chelsea Green Publishing, 2017)
[55] Hon Eugenie Sage, "New Zealand Signs Global Declaration to Cut Plastic Waste", press release, 20 October 2018, https://www.beehive.govt.nz/release/new-zealand-signs-global-declaration-cut-plastic-waste

THE NEW ZEALAND GOVERNMENT HAS COMMITTED TO ENSURING 100% OF PLASTIC PACKAGING CAN BE EASILY AND SAFELY REUSED, RECYCLED OR COMPOSTED BY 2025. THIS REPORT PROVIDES AN EVIDENCE-BASE TO GUIDE THIS CHANGE

A circular economy is aspirational and may not be realised for some time. However, it does stimulate thinking and we might usefully plan for a spiral economy where products, components and materials devalue at end-of-life and some waste is generated, but an increasing fraction is recovered, in the medium term (see Figure 8). This requires short-term strategies that are phased out in the long-term as our societies adopt new habits. For example, we may need to employ new methods to deal with mixed plastic waste, while we establish scalable, economically and environmentally sound models to reuse a package. Striking a balance that can be sustained across society is a complex challenge. Indigenous knowledge can help to address this complex challenge, as illustrated by the speakers and storytellers at the first Ōhanga Āmiomio – Circular Economy Pacific Summit held in Rotorua on 3 April 2019. Aspiration to meet this challenge for plastics guides this report.

1.3.3 Waste hierarchy and the 6Rs

The waste hierarchy and 6Rs (which vary, but here are referred to as rethink, refuse, replace, reduce, reuse and recycle) are helpful frameworks to guide rethinking plastics. Much of the discussion around how to remedy Aotearoa New Zealand's current model of plastic use focuses on improving the recycling system. However, the most impactful step would be to use less plastic where feasible and where it wouldn't cause worse net environmental impacts. This challenges us to innovate and create new materials and new ways of using them that are more sustainable than current practices.

These two frameworks guide our aspiration of shifting from disposal of plastic waste to keeping those resources in use. However, in some instances disposal remains the only available option, so in the short-term it will still be required. We need to develop policies, systems and a culture of practice that support a collective shift away from disposal of plastic waste to diversion, where plastic use is reduced and plastic that is used is reused and recycled, guided by the waste hierarchy and 6Rs.

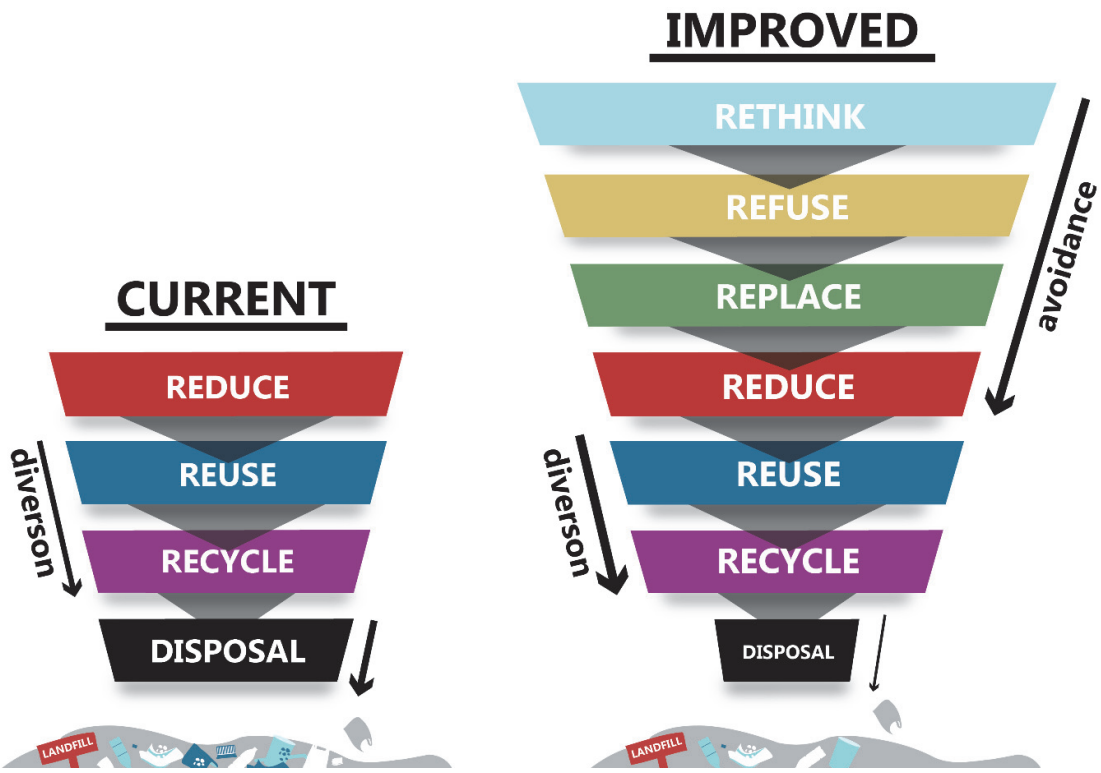


Figure 9 The current waste hierarchy can be updated to prioritise avoiding the use of the material if feasible

1.4 Summary and organisation of this report

The global spotlight is on plastics and there is a groundswell of activity to build on. We are at a pivotal point where we can rethink how we use plastics to reduce the negative impacts while retaining its many benefits. Now is the time to seize this opportunity.

Presenting the motivation for Rethinking Plastics also highlights a series of initial gaps that we believe are fundamental to a collective effort to fix Aotearoa New Zealand's plastic issue – most importantly, that a national plastics action plan is needed to achieve our vision strategically. The remainder of the report brings together an evidence-base and expert opinion, along with specific solutions or recommendation, to guide this change.

After considering the system-wide changes necessary to rethink plastics in Aotearoa New Zealand, our expert panel determined that Rethinking Plastics should have the following workstreams, each captured in a chapter, as follows:

- Changing our relationship with plastics
- Ideas for a more sustainable future – embracing innovation
- Plastics and the environment – life cycle assessment and beyond
- To what extent can we quantify Aotearoa's plastic? New Zealand's data challenge.

2. Changing our relationship with plastics

‘AND I AM A WEAPON OF MASSIVE CONSUMPTION
AND IT IS NOT MY FAULT, IT IS HOW I'M PROGRAMMED TO FUNCTION’

LILY ALLEN, THE FEAR, 2009

In this chapter, we highlight evidence and examples of ways that we can change our relationship with plastics, presented as possible actions that central government, local government, sectors, businesses, communities, the education system and individuals can take, as part of a global community.

2.1 Galvanising system-wide change of plastic use in Aotearoa New Zealand

A fundamental part of rethinking plastics is transforming widespread assumptions and practices concerning plastic. We need to start treating plastic as a valuable resource that is reused and repaired, rather than a resource that is cheap and disposable. This was articulated well by the former Executive Director of the UNEP, Erik Solheim:

> "PLASTIC ISN'T THE PROBLEM. IT IS WHAT WE DO WITH IT. AND THAT MEANS THE ONUS IS ON US TO BE FAR SMARTER IN HOW WE USE THIS MIRACLE MATERIAL."

Being smarter about how we use plastic requires us to look at our current relationship with plastic use and disposal. We can change how we use plastic to be more sustainable in a way that is innovative, benefits society and protects the environment.

Evolving our relationship with plastics requires transformative action across the whole system of plastic use (see Figure 10). We need to create conditions that both encourage and enable more responsible use of plastic and local solutions to the plastic problem, based on new ideas and international best practice. This will have different implications in different parts of our society. Large businesses and government can make policy changes that have an immediate impact, all organisations may consider their procurement and disposal practices, local communities can inspire collective action, and individuals can limit their use of disposable plastic products. Collaboration between groups alongside central and local government working in partnership will help drive widespread change.

New Zealanders need to be supported by clear guiding principles that resonate across sectors and cultures. One such principle may be practicing kaitiakitanga or guardianship of the natural environment (discussed Section 1.3.1). A survey by Keep New Zealand Beautiful (KNZB) identified that 99% of respondents thought it was very (10%) or extremely (89%) important that Aotearoa New Zealand maintains our clean green image.[56] Acknowledging that our image of ourselves is increasingly at odds with our practice of using and disposing of single-use plastic products is a first step to embracing change. Moving away from a system of waste management that relies on burying waste or sending it overseas for another country to deal with, where it could end up in the environment, is part of this change.

In this chapter, we present an evidence base from a collection of initiatives and ideas to guide current and future approaches to support system-wide transformational change of Aotearoa New Zealand's relationship with plastics – ranging from individual actions to national legislation.

[56] Keep New Zealand Beautiful, "National Litter Behaviour Research", 2018

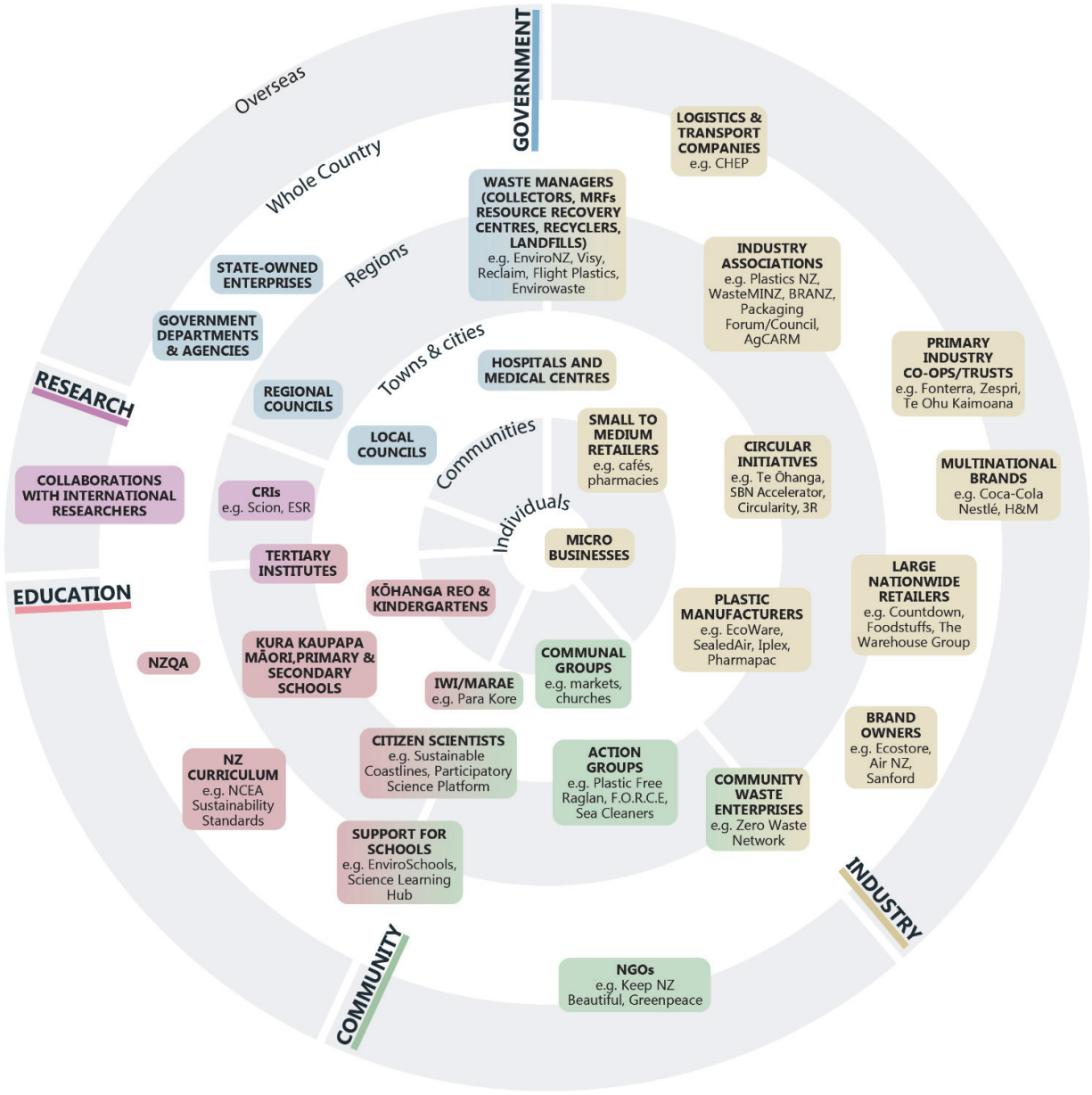


Figure 10 Plastics in Aotearoa New Zealand: an illustration of the wide variety of groups whose actions can contribute to transformational change

2.2 Central government action

The New Zealand Government is in a position to provide leadership that will enable our country to create lasting changes to our relationship with plastics. Policy changes that are implemented here also have the potential to help inform policy changes in other countries. There is goodwill from the community to rethink our relationship with plastics (discussed in Sections 2.6 and 2.8). Now is an opportune time to establish a regulatory framework for plastic to help accelerate change, support good practice and create fair, uniform rules within industry.

Throughout the Rethinking Plastics consultations, stakeholders have noted a desire for increased guidance and regulation from government. Many companies are looking to create change but without clear guidance or sufficient resourcing are worried about investing time and money into initiatives that may not align with longer-term government strategy. Some certainty around a national framework for plastics, including a national plastics action plan, could help ease the transition and accelerate change within industry. Similarly, school and community initiatives may be undermined by people losing faith in the current recycling systems. If circular systems were in place, and people considered these reliable and comprehensive, it would be much easier to encourage responsible disposal of plastic waste.

THROUGHOUT THE RETHINKING PLASTICS CONSULTATIONS, STAKEHOLDERS HAVE NOTED A DESIRE FOR INCREASED GUIDANCE AND REGULATION FROM GOVERNMENT

2.2.1 Current regulations and initiatives related to plastics

The New Zealand Government has several regulations, funding initiatives and programmes related to plastics currently underway, as illustrated in Table 2.

Table 2 Existing initiatives from the New Zealand Government related to plastics

Type	Regulation/Initiative	Details
Regulation	Banned plastic microbeads	The sale and manufacture of wash-off products that contain plastic microbeads for the purposes of exfoliation, cleaning, abrasive cleaning or visual appearance of the product are prohibited[57]
Regulation	Banned single-use plastic shopping bags	The ban applies to all new single-use plastic shopping bags with handles that are made of plastic up to 70 microns in thickness[58]
Regulation	Consulting on mandatory product stewardship schemes (PSS)	The Government is proposing having regulated PSS for six priority products: tyres, electrical and electronic products, agrichemicals and their containers, refrigerants and other synthetic greenhouse gases, farm plastics, and packaging. Consultation submissions closed on 4 October 2019[59]
Funding	$40 million of the Provincial Growth Fund (PGF) for waste initiatives	The PGF sought applications to crowd-source ideas to reduce plastic waste. Applications were due by 30 September 2019[60]
Funding	The Waste Minimisation Fund (WMF)	A fund provided by the waste disposal levy revenue to support projects that aim to reduce waste[61]

[57] Further details available at: https://www.mfe.govt.nz/waste/waste-strategy-and-legislation/plastic-microbeads-ban
[58] Further details available at: https://www.mfe.govt.nz/waste/plastic-bag-ban
[59] Further details available at: https://www.mfe.govt.nz/consultations/priorityproducts
[60] Further details available at: https://www.growregions.govt.nz/assets/governance-meetings/position-papers/provincial-growth-fund-position-paper-waste-projects.pdf
[61] Further details available at: http://www.mfe.govt.nz/more/funding/waste-minimisation-fund

Type	Regulation/Initiative	Details
Programmes	Government-accredited product stewardship schemes (PSS)	Government recognition that a scheme is accredited against requirements outlined in Part 2 of the WMA[62]
Programmes	Green Ribbon Awards	NZ's longest running environmental awards run by the Department of Conservation and the Ministry for the Environment to reward good practice. Note this is currently on hold[63]
Programmes	Resource Efficiency and Circular Economy Transition (RECET) work programme	A work programme to take action on NZ's waste through a circular economy approach focusing on expanding the waste levy, improving recycling, analysing where to invest in innovation and infrastructure, implementing PSS, and developing a national circular economy strategy[64]
Programme	Container return scheme (CRS)	Work underway by the Ministry for the Environment, Auckland Council and Marlborough District Council to develop a national beverage CRS[65]

2.2.2 Summary and opportunities for central government

The current lack of a national strategy and action plan specifically related to plastic makes it difficult for industry, local government, community groups and researchers to know where to invest efforts in rethinking plastics. Government can provide this direction and also lead by example by embedding plastics in their agenda. These issues are addressed in the series of recommendations within recommendations 1 and 3.

Key considerations for implementing these recommendations:

- A national action plan could be strengthened by having a governance group with representation from government, community, business, education and research.
- Efforts should connect with international initiatives, commitments and agreements (described in Section 1.2.1).
- Procurement to include bioplastics could learn from the US BioPreferred system for procurement policies.[66]
- Inclusion of waste and plastics in environment accounting could learn from Australia's approach.[67]
- Demonstration of responsible use of plastics in all government agencies could include revision of procurement practices; responsiveness to new opportunities to improve practice; elimination of unnecessary plastic including single-use cups, cutlery and plates; working with caterers to find hygienic alternatives to plastic; working with healthcare providers to safely reduce the amount of plastic used in medical settings.

[62] Further details available at:: http://www.mfe.govt.nz/node/23986/
[63] Further details available at: http://www.mfe.govt.nz/more/awards/green-ribbon-awards
[64] Further details available at:: https://www.mfe.govt.nz/waste/waste-and-government
[65] Hon Eugenie Sage, "Work Underway for Beverage Container Return Scheme", press release, 25 September 2019, https://www.beehive.govt.nz/release/work-underway-beverage-container-return-scheme
[66] Managed by the U.S. Department of Agriculture (USDA), the goal of the BioPreferred Program is to increase the purchase and use of bio-based products. Details available at: https://www.biopreferred.gov/BioPreferred/faces/pages/AboutBioPreferred.xhtml
[67] The Australian Bureau of Statistics waste data is available at: https://www.abs.gov.au/ausstats/abs@.nsf/mf/4602.0.55.005

2.3 Local government action

Aotearoa New Zealand's local and regional councils play an important role in the relationship that the community has with managing waste, including plastics. Councils' responsibilities to do so are legislated under the Local Government Act 2002, Litter Act 1979, Resource Management Act 1991 and Waste Minimisation Act 2008. The responsibilities of local government that are related to plastics can be broadly grouped into:

- Providing waste management and recycling services
- Managing litter and/or illegally dumped rubbish
- Public awareness, education and engagement with community groups
- Procuring products for civil works and council operations.

Across the country, councils have different systems in place to manage plastic waste and recycling. The systems generally include household kerbside collections, public place collections, and drop-off points at transfer stations and/or community recycling centres. The services and infrastructure are either owned and managed by the council itself or contracted out to private businesses, for some or all of the process. For example, some councils own the landfill where local waste is disposed while others pay to use privately owned landfills. Where landfills are owned and operated by councils, a council's role is more direct with the management of the asset than where private landfills are used. However, when waste management is privatised, the local council still has a responsibility to promote effective and efficient waste management.

Systems implemented by councils can support people to change their practices related to plastic use. One of the big challenges for councils is providing a system that encourages residents to minimise waste production and reduce contamination of recycling. A local study aimed to understand the drivers and barriers for residents to minimise their waste in Palmerston North.[68] The project identified social support, convenient access to sound information, products and services, experiential learning, and affordable and low-effort waste minimisation practices as key drivers of better practices. Councils can draw on these findings to provide tools that will motivate residents to minimise their waste, while also examining broader societal structures that can drive or restrict peoples' efforts to reduce their own waste.

Councils can also support institutions in their district to work together on collaborative projects to reduce plastic use or help to establish facilities that can improve the quality of materials for recycling or composting facilities that accept compostable plastics. There is a great opportunity for regional projects to help new habits take hold in that area and model practices to the rest of the country.

In order to prevent mismanaged plastic ending up in the environment, councils provide facilities such as bins throughout public places. Councils are also responsible for managing litter, cleaning up illegal dumping of rubbish, and in some cases facilitating clean-ups of the environment when these systems are not used or are ineffective. The resources able to be dedicated to these efforts will differ between councils, as will the most effective approach. An Australian study that looked at a variety of methods employed by local councils to better understand which approaches are effective at reducing coastal waste found that the most effective approach was using a combination of outreach programmes (e.g. public education about litter) and providing waste facilities (e.g. kerbside collection and recycling bins). Overall these were more effective than regulatory policies that target specific problematic products.[69] These findings highlight the importance of combining the *why* (educating people) and *how* (providing systems) to support people to change their practices and deal with waste better.

In addition to their role in managing waste and litter, councils are also big users of plastic. Many of the large civil works that councils are responsible for, such as for construction, roading and managing water systems, include procurement of

[68] Farrelly et al., "Action Research and Residential Waste Minimisation in Palmerston North, New Zealand," *Resources, Conservation and Recycling* 91 (2014)
[69] Willis et al., "How Successful Are Waste Abatement Campaigns and Government Policies at Reducing Plastic Waste into the Marine Environment?," *Marine Policy* 96 (2018)

plastic products. Council operations also use plastic products and packaging in day-to-day activities. Therefore, there is an opportunity for councils to demonstrate responsible procurement and use of plastic and lead by example.

2.3.1 Current initiatives and ongoing efforts by local government related to plastics

In Table 3, we highlight some of the current initiatives underway by local councils across Aotearoa New Zealand to mitigate the issues related to plastics, through communicating and educating the public and local businesses, fostering new ideas in the community and through direct action. Further initiatives by local councils are described in the Local Government New Zealand's submission to the Environment Select Committee from May 2018.[70]

Table 3 Ideas and examples of actions that local government could take related to plastics

Action	Example(s) of this practice	Scalability
Communicating and educating the public and businesses		
Provide detailed information about recycling and waste (online and in print)	Many councils have local 'waste guides' online that provide detailed information about a range of products and how to dispose of them e.g. Palmerston North City Council Guru's guide to what goes where, [71] WasteNet Southlands Orange Pages,[72] Timaru District Council's One Planet Guide,[73] and Auckland Council's Recycle Right game.[74] Others provide this information in print, e.g. Kaipara District Council (KDC) supplies a flyer to educate residents about what can and can't be recycled	Easily adaptable to other regions
Promote and encourage good recycling practice	Palmerston North City Council has a 'recycling champion's initiative' where they tag the recycling bin of households who have recycled properly and they go in the draw to win a $50 grocery voucher[75] Auckland Council's Waste Solutions Communications programme during Plastic Free July focused on how to reduce plastic waste, supported by community engagement initiatives from Wastewise Advisors	Other councils can set up similar promotions
Offer educational initiatives and resources related to waste and recycling	Auckland Council has a team dedicated to engaging with the community and businesses around waste reduction and available services. This includes initiatives such as waste minimisation learning sessions at three centres, aimed at schools but community groups also welcome,[76] and the Zero Waste Events resource to educate community groups how to run a zero waste event[77]	Scalable pending resources

[70] In response to the Environment Select Committee's request for information about the scale, impact and sources of plastic pollution, Local Government New Zealand collated initiatives from councils around the country, available at: https://www.parliament.nz/resource/en-NZ/52SCEN_EVI_77896_786/8911111d90c83678ab5d0fc0b96111fe30f55fbe
[71] Further details available at: https://www.pncc.govt.nz/services/rubbish-and-recycling/gurus-guide-to-what-goes-where/
[72] Further details available at: http://www.wastenet.org.nz/Tools/DirectoryHome.aspx/
[73] Further details available at: oneplanet.org.nz
[74] Further details available at: https://www.recycleright.co.nz/
[75] Further details available at: https://www.pncc.govt.nz/services/rubbish-and-recycling/recycling-champions/
[76] Further details available at: https://www.aucklandcouncil.govt.nz/rubbish-recycling/ways-reduce-waste/Pages/book-waste-minimisation-learning-session.aspx
[77] Further details available at: https://zerowasteevents.org.nz/

Action	Example(s) of this practice	Scalability
Work with schools to develop plastic-related educational opportunities	Several councils support external education programmes such as Enviroschools and Te Aho Tū Roa (see Case Study 2.7.2), and Para Kore (see Case Study 2.6.2) See Case Study 2.3.2 for Dunedin City Council below	Nationally scalable, could be supported by initiatives such as the Science Learning Hub
Provide support for businesses to audit and reduce plastic waste	Christchurch City Council provides free support to local businesses through their Target Sustainability programme, including a directory of recyclers, consultants for building design and up to 46 hours of free resource efficiency advice[78]	Adaptable to other regions, pending resources
Foster new ideas in the community		
Partner with or fund community groups and community recycling/ waste recovery centres	Supported by their local councils, Xtreme Zero Waste in Raglan, Innovative Waste Kaikoura and Wanaka Wastebusters have seen those towns become famous for their waste reduction efforts Auckland Council has established eight community recycling centres, with three more underway, as part of an overall resource recovery network vision. All are currently operated by community groups/social enterprises in partnership with Council. The Onehunga site recently had a funding boost of $2.25M from the WMF[79]	Scalable, pending resources – could support applications to WMF
Support initiatives that help develop skills and ideas within the community and local businesses to reduce plastic use	Dunedin City Council (DCC) ran 'Waste Jam' with Startup Dunedin – an event to rapidly explore innovative ideas and build business plans and applications for funding with members of the community.[80] DCC also used waste levy funds to support community workshops by Stitch Kitchen targeted at making tools for people to reduce their plastic use and waste, including textiles (e.g. making product bags, beeswax wraps, and sanitary pads) [81] Auckland Council runs the Waste Minimisation Initiatives Fund, which was used to support roll out of the Again Again (reusable cup system) service in Auckland KDC partners with a local WMF funded organisation to provide waste minimisation learning workshops and education for events, local clubs and schools	Scalable, pending resources
Support local businesses in endeavours to reduce single-use plastics	Hamilton City Council partnered with several local businesses, including waste minimisation experts Mainstream Green and various cafés around the city, to encourage the use of reusable and sustainable products during Plastic Free July[82] Dunedin City Council worked alongside Ideal Cup to launch their programme in the city in 2019 Auckland Council is also in discussion with major supermarket chains over single-use plastics	Other regions can set up similar initiatives, drawing on local expertise and business opportunities

[78] Further details available at: https://ccc.govt.nz/environment/sustainability/target-sustainability/
[79] Auckland Council, "Auckland Waste Management and Minimisation Plan 2018 ", 2018
[80] Further details available at: https://www.startupdunedin.nz/events/2019/7/6/waste-jam
[81] Further details available at: http://www.stitchkitchen.nz/
[82] Hamilton City Council, "Hamiltonians Urged to Make a Plastic Free Pledge This July", press release, 1 July 2019, http://www.scoop.co.nz/stories/AK1907/S00031/hamiltonians-urged-to-make-a-plastic-free-pledge-this-july.htm

Action	Example(s) of this practice	Scalability
Direct action		
Advocate to central government for regulation related to plastics	Local Government Waste Manifesto developed by the WasteMINZ TA Forum comprised of 64 city and district councils from around NZ[83] Local Government New Zealand (LGNZ) have advocated for product stewardship[84] and CDS[85] on behalf of the group of authorities Auckland Council advocates for policy such as product stewardship in their Waste Management and Minimisation Plan (WMMP),[86] and commissioned a cost-benefit analysis of a container deposit scheme to form evidence-base for advocating for such a scheme[87]	Councils can come together to strengthen calls Other councils can join the WasteMINZ TA forum
Collaborate with other councils for consistency in systems and data collection, and economies of scale	Several different councils across Northland are coming together to prepare a feasibility study around options for infrastructure to deal with plastic waste Other groups of councils have shared WMMPs so that their goals of how to manage waste and collection of waste data are aligned, e.g. the Carterton District, Hutt City, Kapiti Coast District, Masterton District, Porirua City, South Wairarapa District, Upper Hutt City and Wellington City councils in the Wellington region have a shared WMMP	Adaptable to other regions
Collaborate with research institutes and citizen science programmes as part of environmental monitoring programmes	Auckland Council collaborated with Scion and the University of Canterbury on a study quantifying microplastics at Auckland's beaches Northland Regional Council is using the Sustainable Coastlines Litter Intelligence framework for monitoring beach litter (see Case Study 5.9.4)	Other regions could connect to similar projects to get baseline and ongoing data
Collaborate with product stewardship schemes to ensure systems are in place for the region	Gisborne City Council works with the Plasback to offer the product stewardship scheme to the region and provides information on their website[88]	Scalable to other regions
Reduce use of single-use plastic at council venues and facilities	Wellington City Council has begun a single-use plastic bottle free trial at its five swimming pools, two gyms, four recreational centres and the ASB sports centre. During plastic free July, Council encouraged pool, gym and recreation centre goers to consider alternatives to single-use plastic bottles Auckland Council is a member of Wai Auckland and RefillNZ and provides free refill of reusable water bottles at pools, leisure centres, and some libraries, and also had a single-use cup free day in all council cafes during Plastic Free July	Nationally scalable

[83] WasteMINZ Territorial Authority Forum, "Local Government Waste Manifesto", 2018
[84] Local Government NZ, "Move to Put Pressure on Waste Producers Welcomed by Lgnz", press release, 9 August 2019, https://www.lgnz.co.nz/news-and-media/2019-media-releases/move-to-put-pressure-on-waste-producers-welcomed-by-lgnz/
[85] Local Government NZ, "Eight Important Issues Debated at Lgnz Agm", press release, 25 July 2016, http://www.scoop.co.nz/stories/AK1607/S00696/eight-important-issues-debated-at-lgnz-agm.htm
[86] Auckland Council, "Auckland Waste Management and Minimisation Plan 2018 ", 2018
[87] Preston Davies, "Cost-Benefit Analysis of a Container Deposit Scheme: Report for the Auckland Council ", 2017
[88] The information brochure for Plasback collections developed by Gisborne District Council and Plasback is available at: http://plasback.co.nz/wp-content/uploads/2016/09/Gisborne-PB-Gizzy-A5.pdf

2.3.2 Case study: A council-led school event to raise awareness about plastic waste

The Dunedin City Council arranged an event to promote the reduction of single-use plastic in students' lunch boxes as part of Plastic Free July 2019. The aim of the project was to engage students and empower them to make a difference by using less plastic. Dunedin City Council provided:

Figure 11 Students with the plastic waste collected from their lunches. Photo credit: Leigh McKenzie

- An information sheet for teachers on how to run the event
- All equipment and resources needed for the workshops, such as irons, beeswax and material
- Facilitation to run a workshop measuring the amount of plastic from a normal lunch day and a discussion around the impact of plastics, including a worksheet-based exercise if visual collection and weighing was not possible
- A workshop for students to make beeswax wraps for students to use
- Facilitation for the follow-up workshop to measure the amount of plastic on the plastic-free lunch day, including a discussion of solutions and alternatives, and a worksheet designed to reveal students' understanding before and after the discussion
- Celebratory morning tea for the classes with the biggest overall and plastic per student reduction
- Advice on some extra activities the school could do to expand the learning opportunities.

> "We finished all of St Francis Xavier School on the programme yesterday (five classes). They went from 128 pieces of plastic to 17 from the whole school! A reduction of 86%! We are seeing lots of the beeswax wraps in their lunches, as well as a lot of parent discussion about Plastic Free Lunches on the school's internal platform 'Seesaw', and every class has had kids telling me about discussions with their parents, and also seen a big reduction in the quantity of plastic before and after."
>
> Leigh McKenzie, Waste Minimisation Officer, Dunedin City Council

This is a great example of how councils can connect with schools as a way of educating the public about the need to reduce how much plastic we use. By providing students with actionable insights on ways to reduce the environmental impacts of single-use plastics, students become empowered to act and share their learnings more widely through their family and community (discussed further in Section 2.6). The 'before and after' worksheet illustrated the learnings that students had about the impact of plastic on the environment, which is critical to support long-term changing practices. Initiatives that engage students in thinking about plastic waste are particularly effective if situated within whole school approaches such as Enviroschools that help ensure they are maintained and refreshed on a regular basis. Such programmes also allow schools to be part of networks that help to hold and grow good practices (see Case Study 2.7.2).

COUNCILS CAN CONNECT WITH SCHOOLS AS A WAY OF EDUCATING THE PUBLIC ABOUT THE NEED TO REDUCE HOW MUCH PLASTIC WE USE

2.3.3 Actions that local councils can take

As well as the examples listed in Table 3, councils could take the following actions to support rethinking plastics in their region.

Figure 12 Use of standardised bin labelling colours for bins at the Matakana Markets

Communicating and educating the public and local businesses

- Employ specialists in managing plastic that would be available to organisations that wish to move toward more responsible practices.

Fostering new ideas in the community

- Encouraging/supporting events to be free of single-use products by providing a library of resources or advice on minimising waste for events.
- Partner with and support local community groups and initiatives in schools or marae such as Para Kore (see Case Study 2.6.2) and Toimata (see Case Study 2.7.2)
- Organise cross-sector hui that encourage creative, locally focused responses to reducing and managing the use of plastic.

Direct action

- Link council plans with iwi management plan and engage with mana whenua regarding environment and waste decisions
- Update procurement guidelines for the council to include sourcing products made from recycled content and minimising the purchase of single-use plastics.
- Adopt the standardised colours and symbols for bin labelling and te reo Māori translations established by WasteMINZ, the Packaging Forum, local councils and Para Kore for all public space bins (see Figure 12). [89]
- Implement processes to filter out plastics in wastewater/stormwater treatment systems – particle sizing could be determined with local wastewater engineers.
- Work with industry bodies and community groups on national solutions and actions (e.g. WasteMINZ, Plastics NZ, Keep New Zealand Beautiful, Sustainable Coastlines (see Case Study 5.9.4), Be a Tidy Kiwi)
- Collect better data on plastic use and waste, set targets for reduction, and get the local community on board
- Lobby central government to impose targeted use-restrictions or levies on undesirable products that create high volumes or particularly problematic materials in certain localities, e.g. tourism or fishing centres.

[89] More information available at https://www.wasteminz.org.nz/sector-groups/behaviour-change/standardising-the-colours-of-mobile-waste-and-recycling-containers/ and https://www.wasteminz.org.nz/sector-groups/behaviour-change/te-reo-maori-resources-for-waste-minimisation/

2.3.4 Current barriers to local government action

- The fragile recycling system – due to volatile markets, reliance on sending recycling offshore due to limited onshore reprocessing capabilities, and poor quality recyclate[90] due to variable practices nationwide precluding effective and enduring educational campaigns. These factors limit councils' options for managing recyclable plastics and their ability to run education campaigns. For example, WasteNet Southland explained that they have been limited in their ability to use radio ads to educate the public about recycling as the radio zone includes Central Otago and the kerbside refuse and recycling systems differ.
- The resourcing required and cost burden of managing plastic waste. The way these manifest differs depending on the size and location of the council, but include issues around increased waste due to tourism (where waste peaks and the cost burden falls on residents); challenges establishing economic systems in geographically dispersed areas with small populations, especially in rural areas and areas far from main centres; limited staff resourcing in smaller councils; limited revenue to move to best-practice facilities (e.g. modern landfills) and the requirement for ongoing maintenance of poor quality or legacy landfills (see Case Study 4.20.2); and the burden of managing waste from specific sectors in that region, due to lack of product stewardship (e.g. fisheries or construction).
- Limited flexibility – due to relying on privately owned landfills, transfer stations, collections and other infrastructure; being tied into long-term contracts which lack incentives for waste reduction; prior investment in infrastructure/technology, which impacts the quality of material councils have to manage – e.g. comingled system vs source separated vs two stream recycling vs automated MRF.
- Limited data on which to make decisions.
- Lack of incentive to embed sustainable plastic use into procurement guidelines.

2.3.5 Summary and opportunities for local government

One of the biggest barriers to action for local and regional councils is the lack of a clear vision and action plan to which councils can align their management of plastics, which precludes willingness to invest in certain infrastructure or systems. Many of the recommendations from the National Resource Recovery Taskforce that were adopted by the government will help to address these issues, including supporting knowledge sharing and standardisation of practices through model contracts and a more nationally coordinated approach (see Section 3.6). These issues are also addressed by recommendations 1, 3 and 4.

Key considerations for implementing these recommendations:

- WasteMINZ has work underway to support standardisation of recycling practices across the country that should be built on.
- Consistency of systems should be balanced against specific needs of each local context. An approach that could be modelled from is WRAP UK's framework for greater consistency in household recycling.[91]
- When establishing new waste management systems (e.g. food waste collection) lessons should be learned from the current recycling fragmentation and a nationally consistent and coordinated approach should be taken. Industrial composters with organic certification cannot take compostable plastics so, to avoid variability and public confusion, the best approach may be to not include compostable packaging in kerbside food waste collection services everywhere.

[90] Plastic sent to and processed in a recycling facility.
[91] Waste & Resources Action Programme (WRAP), "Framework for Greater Consistency in Household Recycling for England", 2016

2.4 Sector-led action

Industry-wide efforts and initiatives can be an effective way to accelerate change by bringing together many groups or businesses with common issues to work together on a collective solution. Practices that lead to overuse or mismanagement of plastic may be commonplace within a particular industry, so the most effective way to transform to a better practice will be to understand the current problematic practices and their drivers, develop evidence-based solutions, put systems in place that facilitate good practice, and get widespread support within the industry to change the practice.

Whole sectors will also be affected by regulatory changes or changes to trade policy at the same time, so may benefit from shared innovation and action, including through economies of scale. This will be particularly true for sectors within Aotearoa New Zealand's export industry, which may risk being shut out of markets if they do not keep up with global trends and regulations in use of plastics in packaging.

Government can work with sectors to find innovative approaches to tackle their plastics issues and determine future policy levers that might help reduce environmental impact from plastics.

Here we address current problematic practices in key industries that use high volumes of plastic or are associated with high loss of plastic into the environment, and highlight opportunities and barriers to bring about transformation. The industries focused on are packaging, fisheries, agriculture, construction, textiles and the plastics manufacturing industry. These are by no means the only sectors who need to take a sector-wide approach to rethinking plastics, but are known high users of plastics or known to be significant contributors of plastics into the environment.

2.4.1 Packaging

As the largest users of plastic globally, ahead of construction and demolition, textiles and automotive, packaging has been an initial focus of many of the efforts to rethink plastics because of its sheer volume, pervasive nature, short timeframe of use, and frequent presence in marine litter clean-ups. Over half of the raw resin imported into Aotearoa New Zealand is manufactured into packaging (see Section 5.3). Countless other packaged goods are imported.

The plastics packaging sector is complex and built on a linear economy approach (make-use-dispose). Collaboration and cooperation are needed to transform the sector into becoming circular (see Section 1.3.2). Aotearoa New Zealand's packaging industry is already engaged in the process of rethinking plastics, with several brands and industry bodies investigating measures to generate less plastic waste. These include:

- The Packaging Forum's industry-led packaging recycling programmes – public place recycling scheme and soft plastics recycling scheme[92]
- Packaging NZ's code of practice including packaging design checklist[93]
- Plastics NZ's work to facilitate collection and local recycling of PP (#5)
- The Sustainable Business Network's (SBN) educational initiatives (see Case Study 2.4.2)
- A number of brands signing the New Zealand Plastic Packaging Declaration[94] and/or the New Plastics Economy Global Commitment.[95]

While some companies are being proactive, there remains much work to be done to transform the culture around sustainable packaging across the whole industry. A fundamental shift in how packaging is designed and viewed is necessary. Government regulation will be necessary to ensure that the best practice exhibited by some brands becomes

[92] More information available at: https://www.recycling.kiwi.nz/
[93] More information available at: http://www.packaging.org.nz/page/15/code-of-practice
[94] The New Zealand Plastic Packaging Declaration of June 2018 was a pledge by 12 multinational and several local businesses to use 100% reusable, recyclable or compostable packaging in NZ operations by 2025.
[95] The New Plastics Economy Global Commitment is led by the Ellen MacArthur Foundation in collaboration with the UN Environment and has been signed by the Ministry for the Environment and many multinationals More information is available at: https://newplasticseconomy.org/projects/global-commitment

standard practice across the industry. An action plan set by the government could guide brands towards using particular material types and avoiding others – aligning these to the systems and infrastructure invested in onshore – to support the transition to a circular economy for plastics.

A FUNDAMENTAL SHIFT IN HOW PACKAGING IS DESIGNED AND VIEWED IS NECESSARY

Transformation at a sector level will require changing:

- **Where the burden of managing packaging at end-of-life sits.** At the moment this is largely felt by local government and the community as a whole, rather than those who use the packaging or put it on the market. A goal of reform would be that brands support the development of product stewardship or take-back schemes to take responsibility for the packaging they put on the market
- **The main cost focus being production of the packaging.** A whole-of-life accounting approach would ensure that life cycle environment impacts and end-of-life management costs are factored in as part of design, material choice and pricing. This should steer brands towards more sustainable packaging choices, including those with onshore solutions for reprocessing, and reduce the use of unnecessary packaging
- **The continual use of virgin materials.** An industry-led approach to address issues around quality of H&S related to food-grade packaging could accelerate uptake and not disadvantage early adopters (see Case Study 2.4.3).

Specific actions individual brands can take are detailed in Section 2.5.

The different types of packaging that need to be considered are:

- **Primary packaging:** in direct contact with the product itself and usually what the consumer receives and has to dispose of. Its main purpose is to protect the product and inform the consumer via labelling – e.g. a milk bottle
- **Secondary packaging:** used to group individual product units, for branding display or for logistical purposes. Sometimes retailers remove this packaging or leave it to sell grouped products, so who needs to dispose of it varies– e.g. plastic wrap to group a pack of tinned food
- **Tertiary packaging:** used to group and protect product units during transit through the supply chain. It is either disposed of by the retailer or collected for recycling – e.g. pallet wrap.

2.4.2 Case study: Empowering brands to make informed packaging decisions

The Sustainable Business Network (SBN), in partnership with the Ministry for Primary Industries, Foodstuffs NZ and New Zealand King Salmon, has run a three-part plastics packaging masterclass series to help empower brands to make informed decisions around their packaging choices. The workshops are based on circular economy thinking and aim to help businesses meet the 2025 packaging commitments. Through these masterclasses, SBN is helping to chart a pathway to 2025 for Aotearoa New Zealand to establish a circular economy for packaging. The strengths of this approach that other sectors could model from include:

- **Prioritising collaboration:** SBN bring people from across the packaging system together to collaborate and share information with businesses who are seeking guidance. This includes packaged goods suppliers, designers and innovators, people with expertise in infrastructure, representatives from the packaging industry, and those in governance roles. Businesses also get to connect with likeminded businesses at these events, which supports shared solutions.
- **Providing practical insights:** SBN ask attendees to identify the aspects of their packaging that are problematic, bring their packaging to the workshops, and prepare questions so that they can leave with a better idea of the possible solutions to address their brand's packaging challenges.
- **Distilling complex information:** Many brands don't have time to wade through the wealth of packaging-related information that's out there. During the workshop, experts share key insights through a series of quick presentations, followed by round-table Q&A sessions to provide further guidance and answer questions. SBN also highlights the most important information (e.g. how to design for recyclability) and additional useful resources in the workshop materials.
- **Sharing information further:** Because the capacity of the workshops is limited, SBN will publish output reports from the series to help disseminate the information to the wider business community.
- **Trusted facilitation:** Being an impartial organisation in the plastics, packaging and waste sectors has helped SBN to build trust and enable collaboration. Attendees expressed how necessary it is for an unbiased party to be doing such work, due to distrust and alternate agendas at play.

Addressing the following challenges faced by SBN could help improve the effectiveness of future educational initiatives for packaging and other sectors.

- **Financial barriers:** Due to a shortfall between investment and the high upfront costs of establishing and running the series, businesses had to pay to attend. This mostly limited attendees to larger companies with enough resource and created tension with Councils and Government agencies who want to participate in but not sponsor the initiative. Grants or weighted costs for different sized businesses may help address this issue.
- **A crowded space:** To avoid duplicated efforts and support collaboration, it is important that the many stakeholders and organisations have clearly defined roles and are willing to collaborate and share information. Resource constraints that limit active involvement and a lack of communication and transparency can make progress challenging. Regulation that means all organisations in the sector are on even footing with a common goal may support shared action.
- **Communicating to a diverse audience:** the range of businesses and other organisations that want information on plastics and packaging vary considerably. Developing digestible information in a format that any business can access is challenging. With larger uptake, messaging could be directed at similar groups within an industry.
- **Urgency:** The workshops are in response to SBN's members asking for clear guidance on plastics and packaging. Many brands urgently want answers and fixes to their packaging problems, but may be limited in how much time and resource they can dedicate to making an informed decision. A national plastics action plan could give businesses the direction they are seeking to take action immediately.

2.4.3 Case study: Incentivising use of recycled plastic

The Association of Plastic Recyclers (APR) in the US established the 'Recycling Demand Champions' initiative to make plastic recycling a mature and stable market.[96]

The aim is that by having companies commit to purchasing post-consumer recycled plastic, there will be consistent and reliable demand and the market will improve, which in turn will drive investment, and improve stability of supply and quality.

Companies become 'Recycling Demand Champions' by signing a commitment to:

- Provide future actions and report data on progress (to be aggregated for the whole initiative)
- Choose to purchase items containing post-consumer recycled plastic (the scheme supplies vendor information) *or* use post-consumer recycled plastic in a product (or increase use)
- Purchase and report item(s) within 12 months.

The program commenced in 2018 with 10 companies, including Coca-Cola, Target & Proctor and Gamble. In that year, the companies increased their purchasing of post-consumer recycled LDPE (#4), HDPE (#2), PET (#1) and PP (#5) by 6.8 million pounds (around 3000 tonnes), which was estimated to create over 90 jobs, reduce the equivalent greenhouse gas emissions as 1,700 cars driven for a year, and use the equivalent of all the plastic recyclables from Cambridge, Massachusetts for one year. APR actively promotes the companies that are part of the program.

Figure 13 Bales of clear PET (# 1) ready to be sent for recycling. Photo credit: Stephen Harris

A similar initiative where Aotearoa New Zealand companies commit to purchasing post-consumer recycled plastic could be an effective way to improve the pull-through of recycled content in the market and encourage more circular approaches to product design, with particular focuses depending on the quality and hygiene requirements of the application. Some of these multinational companies are already using recycled plastic in products sold locally, such as Coca-Cola using 100% recycled PET (#1) for all plastic bottles smaller than 1-litre and all water bottle bottles sold in Aotearoa New Zealand,[97] and these efforts could be built on. The initiative could further extend to include ocean waste plastics, building on the model used by Ecostore and international best practice (see Case Study 2.5.2).

A SIMILAR INITIATIVE WHERE AOTEAROA NEW ZEALAND COMPANIES COMMIT TO PURCHASING POST-CONSUMER RECYCLED PLASTIC COULD BE AN EFFECTIVE WAY TO IMPROVE THE PULL-THROUGH OF RECYCLED CONTENT IN THE MARKET AND ENCOURAGE MORE CIRCULAR APPROACHES TO PRODUCT DESIGN

[96] Further details available at: http://www.plasticsrecycling.org/recycling-demand-champions/demand-champion-companies
[97] Coca-Cola, "Coca-Cola Oceania, Amatil Announce New Recycling Plan", press release, 31 July 2019, http://www.scoop.co.nz/stories/BU1907/S00770/coca-cola-oceania-amatil-announce-new-recycling-plan.htm

2.4.4 Fisheries

Though not one of the sectors with the highest use of plastics, there is ample evidence that the global fisheries industry is a significant contributor to marine plastic waste. It is estimated that about a fifth of all marine plastics pollution is actually generated from maritime uses, with commercial fisheries being a large contributor.[98] At least 46% of plastic waste in the Great Pacific Garbage Patch comes from fisheries,[99] and the UNEP estimates at least 640,000 tonnes of fishing gear is lost every year.[100]

Marine-based fisheries operations depend on a wide range of plastic materials such as plastic fishing line, ropes or netting, soft plastic lures, light sticks, floats, bins and other containers, safety and wet weather equipment, and scientific tags.[101] These are used in an environment where plastic is easily damaged or eroded and where there is limited infrastructure or capability to deal with waste.

Aotearoa New Zealand's fisheries sector should prioritise rethinking plastics because:

- **Our wellbeing is connected to the wellbeing of the oceans**. Māori have a deep connection to the sea (Tangaroa), and this is shared by most other New Zealanders. In addition to the commercial fishing industry, our community depends on a healthy marine environment for recreational fishing. There is both an expectation and a shared responsibility to keep it free of plastic pollution. This responsibility extends to the Pacific. Given the interconnected nature of the ocean, Aotearoa New Zealand has a responsibility to demonstrate kaitiakitanga to reduce the impact of our fishing industry on our Pacific partners.
- **We have the fourth largest Exclusive Economic Zone (EEZ) in the world** – roughly 15 times our land area and with 15,000 km of coastline. Our EEZ contains much of the commercial catch that we export.[102]
- **Our seafood industry is a significant contributor to exports** ($1.8 billion in 2017) and employment (13,000 full time workers) and approximately 50% of fisheries quota are owned by iwi/Māori.[103] Continued plastic pollution could impact the industry, including Māori business.
- **Influencing regional norms and reforming practices to minimise the prevalence of plastics in the fisheries sector could help our Pacific partners.** The oceans and fisheries are vital to Pacific Island countries' social, cultural and economic wellbeing. Aotearoa New Zealand contributes significant resource to supporting Pacific Island states to sustainably manage fisheries and marine resources for maximum economic, social and environmental benefits, and our learnings could be shared with these fisheries-dependent countries.
- **It could protect our reputation as a leader on oceans issues.** With fisheries plastic gaining increasing international attention, poor practice by Aotearoa New Zealand may pose a reputational risk (as highlighted by the Rapa Nui example in Section 5.9.3) but best practice may present an opportunity to show international leadership on the issue.

Aotearoa New Zealand has legislative frameworks in place which implement the International Convention for the Prevention of Pollution from Ships (MARPOL Annex V).[104] MARPOL provisions prohibit the discharge of waste, including plastics, from all ships in Aotearoa New Zealand waters and on the high seas. Aotearoa New Zealand has also signed up to other international controls for the discharge of plastic from fishing vessels, including the Western and Central Pacific

[98] Li et al., "Plastic Waste in the Marine Environment: A Review of Sources, Occurrence and Effects," *Science of the Total Environment* 566 (2016)
[99] Lebreton et al., "Evidence That the Great Pacific Garbage Patch Is Rapidly Accumulating Plastic," *Scientific Reports* 8, no. 1 (2018)
[100] G. Macfadyen, T. Huntington, R. Cappell, Abandoned, lost or otherwise discarded fishing gear. UNEP Regional Seas Reports and Studies No. 185; FAO Fisheries and Aquaculture Technical Paper, No. 523. Rome, UNEP/FAO, 2009.
[101] Described by Fisheries New Zealand in a submission to parliament about the scale, impact and sources of plastic pollution in New Zealand, available at: https://www.parliament.nz/resource/en-NZ/52SCEN_EVI_77896_784/f7982e48f202667ec63823ff7e29f6d722df70ef
[102] Details of New Zealand's maritime zones and boundaries available at: https://www.mfat.govt.nz/en/environment/oceans/our-maritime-zones-and-boundaries/
[103] Industry key facts from Seafood New Zealand, available at: https://www.seafoodnewzealand.org.nz/industry/key-facts/
[104] MARPOL annex V regulations are enacted in under the Maritime Transport Act 1994 and a range of marine protection rules, administered by Maritime NZ in Aotearoa New Zealand. Further details about MARPOL are available at: http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-for-the-Prevention-of-Pollution-from-Ships-(MARPOL).aspx

Fisheries Commission (WCPFC),[105] the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR),[106] and the South Pacific Regional Fisheries Management Organisation (SPRFMO).[107] These also prohibit the discharge of plastic waste, and the disposal of fishing gear (with exceptions around accidental loss and safety).

Despite these existing regulations, there is evidence that Aotearoa New Zealand's fisheries companies are contributors to this global problem – most of the plastic fish bins washed up on Rapa Nui (Easter Island) were identified as Aotearoa New Zealand brand names (see Section 5.9.3). However, we currently lack the data needed to quantify our industry's contribution to this problem (discussed further in Chapter 5). These findings suggest that there would be benefit in government partnering with Aotearoa New Zealand's fisheries sector to explore practical approaches to address the operational challenges that lead to marine plastic pollution. Sector-wide dissemination of best-practice approaches will be critical to ensure that these become standard practice, and may be further supported by regulatory measures.

Determining which approaches to take to rethink plastics in the fisheries industry should be guided by evidence and informed by industry experience. Data presented by a UN expert group at the Pacific Island Forum highlighted the different activities that lead to marine waste from fisheries, based on 20,000 MARPOL violations reported by observers on fishing boats from 2003-2018. The approximate proportions were:

- 77% waste dumped overboard (38% being plastics)
- 7% abandoned or lost fishing gear
- 16% other and non-plastic waste (e.g. oil spillages).

Though these estimates are not specific to Aotearoa New Zealand, and the level of non-compliance by local fisheries is unknown, they can be used to prioritise and guide efforts to reduce the impacts associated with fisheries-related plastic pollution.

Waste dumped overboard

Dumping waste overboard from fishing vessels is the result of a lack of infrastructure or capability to deal with waste on-board underpinned by elements of a cultural norm that it is an acceptable or standard practice. Priority should be given to supporting a change in this practice. Approaches could include:

- Workplace education about the impacts of marine pollution, including access to information and resources. This could continue best-practice examples such as Tina Ngata's talk at the Māori Fisheries 2019 Conference where she explained the broad impacts of microplastics and current studies underway, to share that knowledge with members of the industry.[108]
- Establishing a collaborative environment that promotes the sharing of knowledge and ideas for mitigating issues related to waste dumping within industry, and between industry and government.
- Implementing flat fees for waste disposal – with plastics free or reduced – in port facilities that receive waste (all major ports in Aotearoa New Zealand)[109] to avoid the disincentive of bringing back less waste to reduce costs. A fixed fee has been implemented in the Port of Rotterdam in the Netherlands.[110] Though the results of the effectiveness are not yet clear for the port, it has been estimated that this approach could lead to an impact reduction of 5%–20%.[111]
- A requirement to record all plastic that is taken into the setting and audit to confirm return.

[105] Further details available at: https://www.wcpfc.int/home
[106] Further details available at: https://www.ccamlr.org/en/organisation/home-page
[107] Further details available at: https://www.sprfmo.int/
[108] Tina Ngata's speech at the Māori Fisheries Conference 2019 is available at: https://teohu.conference.maori.nz/2019-speakers/tina-ngata/
[109] More information available at: https://gisis.imo.org/Public/Default.aspx
[110] More information available at: https://www.portofrotterdam.com/sites/default/files/waste-disposal-in-the-ports-of-rotterdam-rijnmond.pdf?token=uCU26_ZJ
[111] Common Seas, "Plastic Drawdown: A New Approach to Addressing Plastic Pollution from Source to Ocean. Summary for Policy Makers," (2019)

Abandoned and lost fishing gear (ghost gear)

Fishing gear that has been abandoned, lost or discarded at sea harms fish or other marine life. Ghost gear such as big nets, buoys, fish aggregating devices (FADs), and fishing lines can snare birds and marine mammals. Over time, the gear breaks down into microplastics and contributes to the environmental hazards caused by this (discussed in Chapter 4). The scale of ghost gear is considerable. As a result, ghost fishing is considered a growing threat to marine life that urgently needs to be addressed. Research looking at Australian and Indonesian fisheries management shows that gear loss or abandonment at sea is ultimately the result of a chain of events, rather than one particular practice. [112] These are due to both operational and regulatory fisheries management challenges, and a multi-faceted approach is needed to prevent gear loss.

Aotearoa New Zealand has already taken some steps to prevent abandoned and lost fishing gear, which could be built on. The legislation and voluntary initiatives outlined in Section 1.2.1 address gear loss, FADs are not used in Aotearoa New Zealand waters (although they are sometimes used by certain vessels that fish on the high seas), and Aotearoa New Zealand supported the draft Food and Agriculture Organisation's (FAO) Voluntary Guidelines on Marking Fishing Gear in 2018.

Further approaches to prevent or remediate lost gear could include:[113]

- Deposit return scheme for fishing gear to increase collection and recycling rates at end-of-life (the Icelandic fisheries' system collects an estimated 59% of plastic material and recycles 90% of the materials that are considered recyclable)
- Regular gear maintenance (renewals/repairs) to decrease gear loss
- Mandatory marking of fishing gear to allow tracing back to the vessel (which would support audits of reported gear loss). There are international efforts underway to get mandatory marking schemes in place, building on voluntary guidelines mentioned above
- Modifying gear to reduce likelihood of snagging
- Materials innovation to make nets less harmful in the ocean in the long-term (e.g. moving to marine biodegradable plastic FADs), including release mechanisms to render them less harmful if they break free
- Gear recovery campaigns to collect decommissioned marine farming equipment (note the value for money of gear recovery for lost fishing equipment compared to other approaches has been questioned)[114]
- Reporting of gear loss for subsequent gear recovery campaigns
- Using technology to improve the traceability of lost gear for recovery (when coupled with a payment system that rewards return or disclosure of lost gear it is estimated to reduce impact by up to 20%)
- Zoning controls to limit or prohibit the use of different types of gear that are known to cause damage and loss of gear when they come into contact (gear conflict) (estimated to reduce waste generation by up to 20%).[115] This is not known to be a significant issue in in Aotearoa New Zealand waters as drift netting, which is the worst offender when it comes to ghost fishing gear, is already banned.

[112] Richardson et al., "Understanding Causes of Gear Loss Provides a Sound Basis for Fisheries Management," *Marine Policy* 96 (2018)
[113] Gilman, "Status of International Monitoring and Management of Abandoned, Lost and Discarded Fishing Gear and Ghost Fishing," *Marine Policy* 60 (2015)
[114] Brown et al., "Ghost Fishing in European Waters: Impacts and Management Responses," *Marine Policy* 31, no. 4 (2007)
[115] UK NGO Common Seas developed the Plastic Drawdown framework which includes numerous policy initiatives to reduce ocean plastics and estimates of how much each could reduce impacts https://commonseas.com/projects/plastic-drawdown

Best practice becomes standard practice

Some seafood companies are leading the way for change, and the wider industry could follow suit. Voluntary compliance is unlikely to get the industry to the transformational level of change that is needed, in the urgent timeframe required, to mitigate plastic pollution effects on the marine environment. Regulation can be used to ensure that the best practice demonstrated within the industry becomes standard practice.

Sanford Ltd is an example of a fisheries company in Aotearoa New Zealand leading the way in some areas. The company has committed to reduce plastic waste by 70% and reuse or recycle those plastics that remain necessary across operations, by 2025.[116] A range of additional initiatives are in progress, including packaging innovations, phasing out plastic in retail operations, and ongoing roll-out of operational innovations, such as eco-ties in aquaculture operations. The company is also undertaking a gear recovery campaign in the Marlborough Sounds, as well as a targeted engagement programme, raising awareness of marine plastic pollution. Similar efforts to reduce, replace, remediate and educate should be taken by the whole industry.

Connect internationally

There are many international initiatives that could be used as a platform for progressing action in this area. In addition to the conventions and commitments outlined above and in Section 1.2.1 there are opportunities for Aotearoa New Zealand's fisheries industry to connect to international efforts to prevent derelict fishing gear. For example, the National Oceanic and Atmospheric Administration (NOAA) Marine Debris Program in the US is working with fishers to provide a place to dispose of fishing gear free of charge and support new, innovative prevention strategies through technological advancements in fishing gear. The program has collected more than 2.1 million pounds (around 950 tonnes) of gear from 41 locations across the US so far.[117] Similarly, the Department for Environment, Food and Rural Affairs (DEFRA) in the UK is partnering to support efforts to monitor and decrease ghost fishing.

[116] Sanford Ltd Annual Report 2018, available at: https://www.sanford.co.nz/assets/announcements/Sanford-Annual-Report-2018-web.pdf
[117] The U.S. Department of Commerce's National Oceanic and Atmospheric Administration has a Marine Debris Programme with a number of initiatives to reduce the impact of marine debris. Details available at: https://marinedebris.noaa.gov/

2.4.5 Agriculture

In Aotearoa New Zealand, agriculture is a high-use sector for plastics, using 15% of plastic products manufactured onshore (see Section 5.3). In agriculture, plastic is used directly in the environment, so there is a high risk of plastic leaking into the environment in these settings, and the industry may be vulnerable to impacts from plastic pollution. For example, the potential for microplastic contamination to impact on soil production or other agricultural outputs is unknown (as discussed in Section 4.15), but should be considered.

Figure 14 The renewable, biodegradable net clip developed for the viticulture industry by Scion. Image credit: Scion.

The use of plastics in agriculture has increased significantly over the years, though we lack data to quantify the exact types and amount of plastic used (discussed in Chapter 5). Many practices that did not use plastic in the past now do, such as storage of hay or silage on farm paddocks. Each practice that uses plastic requires careful consideration of whether:

- Systems could be developed to increase recovery or reduce environmental leakage from use: Building on existing approaches such as the product stewardship schemes for agricultural chemical containers and bale wrap (see Case Study 2.4.6).
- Plastic is the best material to use: For example, AstroTurf is known to shed microplastics into the environment where it is laid.
- Innovation is required to reduce downstream impacts. For example, in viticulture and agriculture it is common practice to use plastic clips to keep various types of netting down and these often fall off into the environment when the netting is removed. The reason these clips escape into the environment is the speed at which the nets are removed. Rather than individuals carefully removing each clip, which takes time, an innovation to make clips out of a material that can compost in the environment may be a better solution, as shown by the biodegradable vine net clip developed by Scion in partnership with manufacturers EPL Group (see Figure 14).[118]
- Reduction is possible.
- A change in practice is necessary.

The agricultural industry is broad. Within the industry, particular groups with common practices may come together to tailor solutions and government can connect with these groups.

[118] The biodegradable vine net clip was highly commended for the best environmental product category at the Plastics NZ awards 2019. Details available at: http://www.plastics.org.nz/news-events/new-zealand-plastics-industry-design-awards/2019-design-awards-finalists/biodegradable-wine-net-clip

2.4.6 Case study: Product stewardship for agricultural plastics

Farms and agricultural properties can generate a lot of waste and traditionally the approach to dealing with this waste has involved the 3Bs – burning, burying or bulk storing. In surveys that took place in 2013 and 2014, almost all farmers admitted to using the 3Bs as a waste disposal strategy.[119] The environmental consequences of these disposal methods meant that transformation across the sector was needed to support better practice.

To address problematic plastic waste issues on farms, two product stewardship schemes were developed in 2010. These schemes involve educating and supporting farmers to deal with plastic waste in a circular way. Agrecovery supports stewardship of plastic agrichemical containers and Plasback began supporting stewardship of plastic bale wrap, and has now expanded to various other plastic products used on farms. These schemes have been effective because they have informed farmers about the environmental impacts of mismanaging waste, and then provided systems that enable farmers to then manage their waste in the right way. It is important to develop knowledge, but without structures or facilities such as rural modern landfills, transfer stations or resource recovery facilities in place to support better practice, it won't lead to transformative change. Another strength is that the schemes have industry support resulting in no or reduced costs to farmers (the Agrecovery scheme is free for brand owners that participate, but Plasback charge at purchase and collection[120]), removing a cost barrier for uptake and making it easy for people to engage in the new practice.

Testimonials from Agrecovery highlight how the programme has driven and supported the change in practice for users.[121] These include:

- **Educating people about caring for the environment:** "Good environmental practices are important; we have to think about the next generation and the generation after that."
- **Providing the system to enable better practice:** "When the programme became available we thought 'yeah it is the right thing to do, we'll use it'."
- **Making it simple and accessible:** "Recycling with Agrecovery is a really simple process and just a no-brainer. You've got chemical containers that would be a problem and someone is offering to take them away. Why would you not do that?"
- **Enabling a new habitual practice:** "It is now becoming so important that we will move to only use chemical companies that do support Agrecovery."
- **Sharing their new knowledge and encouraging others to do the same:** "As we move into the future the use of Agrecovery is certainly something that we will encourage and make our customers more aware of."

These testimonials demonstrate that a better alternative for managing waste is available and when people understand the environmental consequences of waste mismanagement, they are willing to change their practices and adopt the new system. Though voluntary until now, there is quite high uptake of these schemes. Ideally uptake would be increased to near universal. If voluntary mechanisms are relied on, using accreditation and auditing by industry is a way to increase participation. The alternative approach is for government to declare one or both of the products involved as priority products and make stewardship mandatory, which is currently under consultation by the Ministry for the Environment (as detailed in Section 2.2.1).

[119] GHD, Non-natural rural waste: Site survey data analysis (2013), prepared for Environment Canterbury Regional Council; Available at: https://api.ecan.govt.nz/TrimPublicAPI/documents/download/1851763 and GHD, Rural waste surveys data analysis: Waikato and Bay of Plenty (2014), prepared for Waikato Regional Council; Available at: http://www.waikatoregion.govt.nz/assets/PageFiles/30542/TR201455.pdf
[120] Further details available at: https://plasback.co.nz/faqs/
[121] Further details available at: https://www.agrecovery.co.nz/farm-for-our-future/

2.4.7 Construction

The construction sector is the second biggest user of plastics globally, after packaging, and in Aotearoa New Zealand uses 15% of the plastic products manufactured onshore (see Section 5.3). The use of plastics in building and construction has increased in recent years as a result of more plastic being used in construction as new products (e.g. plastic building shrink wrap) and many established building materials changing to plastic from alternatives (e.g. plastic pipes). However, as discussed in Chapter 5, we do not know exactly how much plastic is used in buildings in Aotearoa New Zealand or by how much use has increased. There is a great need for reliable research and data on the composition and volume of construction waste in order to address issues of plastic waste in the industry.

Figure 15 Expanded polystyrene from a construction site entering the waterways.

Common plastics used in building and construction include:

- A range of products, including building shrink wrap, insulation, window frames, cladding, guttering, sealants and adhesives, paints and other coatings, packaging (see Section 2.4.1) and furnishings (carpets, luminaires, furniture), both made locally or imported.
- Many different types of plastic, including a wide range of resins and raw plastics with chemical entities outside Types 1 to 7 (e.g. polyurethanes).

The increases in plastic use will be environmentally beneficial in some instances and detrimental in others. This requires further analysis on a product or application basis, taking into account LCA and environmental leakage (as discussed in Chapter 4). Practices related to plastic use in the construction industry that need to be addressed include:

- **Practices on building and demolition sites that lead to plastic entering the environment.** For example, expanded polystyrene (EPS) has great propensity for breaking off and is prone to being poorly handled on construction sites (see Figure 15). Plastics NZ's EPS Sector Group has developed a best-practice storage and handling guide that will be provided to companies upon purchase of construction EPS products. This best practice needs to become standard practice across the industry. Practical end-of-life options need to be developed after certain uses, such as for EPS used as fill or in flooring. Opportunities to encourage changing practices in the construction industry – as has been achieved by banning lead-based paints and asbestos – can be taken from other sectors. For example, a similar accreditation scheme to the one used by the plastics manufacturing industry (see Case Study 2.4.11) could be established to ensure zero leakage of plastics into the environment from a construction site.
- **Inefficient use of resources and waste generation.** A significant proportion of waste to landfill comes from the building and construction sector (see Chapter 5). As part of a pilot trial conducted by Christchurch City Council in 2014, the 'Resource Efficiency in the Building and Related Industries (REBRI) certification scheme' was developed to promote, advocate and assist resource efficiency measures. Sector-wide adoption of such a scheme or integration of these measures into existing certification schemes could help to improve efficiencies in plastics use and reduction of plastic waste in the industry.
- **Increased use of plastic overall, including new uses of plastic such as building shrink wrap, without recycling options** (see Figure 16). For example, limited end-of-life options for building shrink wrap are being reported by industry. The sector could be supported to reduce use of virgin plastic materials and develop systems to ensure reuse or recycling of plastics via product stewardship schemes. Opportunities also exist to accredit and/or mandate the

existing product stewardship schemes for PVC (#3) pipes.[122] Sufficient onshore recycling infrastructure is required in order for these approaches to work.

- **Leakage of plastics into the environment caused by weathering of plastic products.** The Building Research Association of New Zealand (BRANZ) reported on this in 2007 and highlighted that manufacturers and specifiers need to be aware that choosing specific additives to prevent weathering is crucial to make lasting products.[123] It is also important to understand the toxicity implications of these additives, if applicable (discussed further in Section 4.14).
- **Sustainable material choice, including plastics.** Best practice sustainable material choice could be facilitated via guidance and decision-support tools for architects, building scientists, quantity surveyors and other professionals (e.g. using life cycle assessment (LCA) – see Section 4.3) and through uptake of voluntary accreditation systems such as Homestar and Green Star.[124]
- **Use of plastics from non-renewable sources.** BRANZ reported in 2008 that there is potential for bioplastics in Aotearoa New Zealand's building industry, but that specific construction applications may be limited due to the trade-off between durability and biodegradability for some of these materials.[125] Collaboration with materials scientists to meet the specific needs of the construction industry could help to address this issue.

Figure 16 Example of building shrink wrap on a building worksite on Karangahape road

A transformative approach that could help to reduce the amount of plastic leaking into the environment from construction sites, as well as reduce the overall amount of plastic waste and ensure higher rates of recycling and reuse for products used in this industry, is to design for deconstruction and build offsite. The Clever Core facility owned by Fletcher Building is an example of offsite home manufacturing which is cited to reduce building waste by up to 80% per home built.[126] Different approaches are likely to be needed for larger commercial construction sites and residential construction waste. A greater understanding of the waste needs and initiatives applicable to residential construction sites is needed (see Case Study 5.7.11). A Building Research Levy-funded project seeks to undertake an industry-wide survey and provide information on the extent of the issue and gauge industry opinions on possible solutions.

[122] Further details available at: https://www.plastics.org.nz/environment/environmental-news/nz-s-pvc-recycling-scheme
[123] https://www.branz.co.nz/cms_show_download.php?id=9dd080c1f07cb888fc181607b5fdf5d61a9c0843
[124] A rating system to encourage the property and construction sectors to design products in a more sustainable, efficient and productive way that is independently verified.
[125] Marston, "Bio-Derived Polymers and Composites", 2008
[126] Further details available at: https://fletcherbuilding.com/news/fletcher-building-opens-new-zealands-largest-offsite-home-manufacturing-facility/

2.4.8 Textiles

The Ellen MacArthur Foundation estimates that 63% of virgin feedstock used for clothing is plastic.[127] Global estimates put the textiles industry as the third-largest consumers of plastic (see Figure 3) and indicate that around 1 billion tonnes of polyester, polyamide and acrylic fibres have been produced since 1950.[128] These effects are largely due to the exponential increase in synthetic textile production as a result of the rise of the fast fashion industry. In addition to the concerns around low recycling rates for clothing (reported to be <1%), a big concern for the textile industry is its contribution to plastics entering the ocean through washing. Synthetic clothing is one of the biggest sources of microplastics in the environment, as the process of washing plastic-based textiles causes microfibres to shed which then enter the waterways (see Figure 17). Recent research showed that the delicate wash releases on average 800,000 more microfibres than other cycles which use less water.[129]

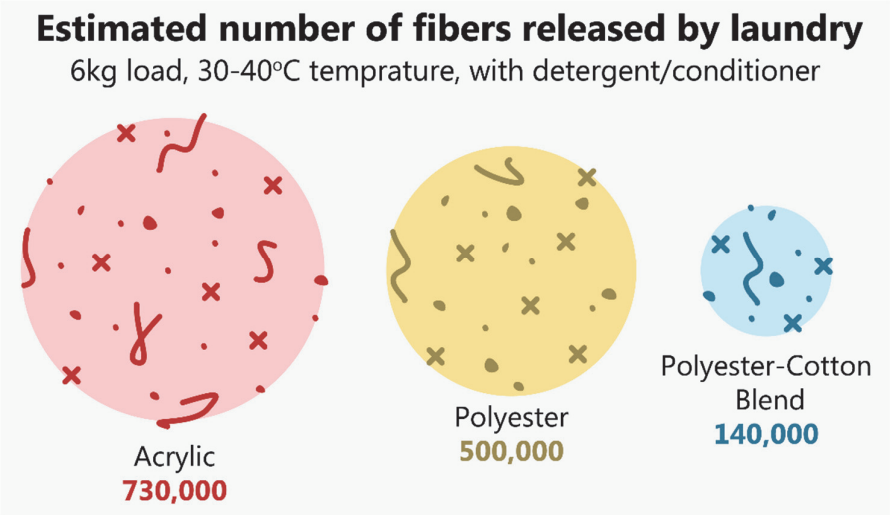


Figure 17 Estimates of the number of fibres released from acrylic, polyester and polyester-cotton blend clothing during a laundry cycle. Figure adapted from Statistica.

The case for rethinking the global textiles system, starting with clothing, has been made by the Ellen MacArthur Foundation.[130] There are multiple issues with the current way textiles are made, used and disposed, most of which fall outside the scope of this report. The lack of infrastructure to manage clothing in a circular way, which leads to most textiles ending up in landfill at end-of-life, compounds the issues related to plastic-based textiles. Aotearoa New Zealand's efforts to rethink plastics need to factor in synthetic textiles. Sector-led action in Aotearoa New Zealand is required to drive transformational change in how we use and dispose of clothing, with a particular focus on phasing out materials that release synthetic microfibers and microplastic fragments (e.g. glitters, sequins and embossed images). This can build on existing best practice, such as the textile reuse programme established by The Formary.[131]

In the short term, mitigating the effects of microplastic fibres will require measures to physically stop or filter out these particles, and in the long term, new materials and production processes drastically reduce microfibre shedding are needed (see Case Study 4.20.4). The limited manufacturing of textiles in Aotearoa New Zealand means that the focus on rethinking plastics needs to also factor in brands and retailers, and to consider import measures, such as content environmental labelling (see Case Study 5.2.3). There are also severe infrastructural limitations for onshore textile recycling in Aotearoa New Zealand. The textile manufacturing and retail industries need to be supported by government to take a collective approach to move towards a circular economy for clothing, with appropriate systems and infrastructure to do so. Some companies are leading the way in demonstrating circular principles in action in the textile industry (see Case Study 2.4.9). This best practice needs to become standard practice across the industry.

[127] Ellen MacArthur Foundation, "A New Textiles Economy: Redesigning Fashion's Future ", 2017
[128] Geyer et al., "Production, Use, and Fate of All Plastics Ever Made,"
[129] Kelly et al., "Importance of Water-Volume on the Release of Microplastic Fibers from Laundry," *Environmental Science & Technology* (2019)
[130] Ellen MacArthur Foundation, "A New Textiles Economy: Redesigning Fashion's Future ", 2017
[131] More information available at: http://www.theformary.com/

2.4.9 Case study: Recyclable shoes

As part of its recent pledge to use only recycled plastics by 2024, Adidas revealed a new sneaker made from 100% recyclable materials.[132] Driven by a connection to environmental organisation Parley for the Oceans, the new sneakers are made from recycled polyester recovered from plastic littered on beaches – intercepting it before it reaches the ocean. One of the most innovative developments is that every part of the sneaker is made from the recycled plastic and the way the sneaker was made means it can be fully recycled at end-of-life. Actions that have made Adidas's approach effective include:

- Making a public pledge
- Connecting to action groups
- Materials innovation
- Challenging the linear economy.

Figure 18 An Adidas shoe made from recycled polyester recovered from plastic littered on beaches. Source: adidas.co.nz

EVERY PART OF THE SNEAKER IS MADE FROM THE RECYCLED PLASTIC AND THE WAY THE SNEAKER WAS MADE MEANS IT CAN BE FULLY RECYCLED AT END-OF-LIFE

[132] Further details available at: https://www.adidas-group.com/en/media/news-archive/press-releases/2019/adidas-to-produce-more-shoes-using-recycled-plastic-waste/

2.4.10 Plastics manufacturing industry

Ultimately, plastics manufacturing is at the top of the chain of all plastic that is produced and used, and therefore changes to current practices within this industry could have huge flow-on effects to support efforts to rethink plastics.

An analysis for the European Commission on ways to reduce microplastics at source identified supply chain accreditation for pre-production pellets as having the greatest potential to reduce environmental impact and be the most cost-effective of all measures studied.[133]

It is worth noting that many of the plastic products used in Aotearoa New Zealand are manufactured overseas and imported (though we don't know exactly how much and which types – see Section 5.2.2). Therefore, our local plastics manufacturing industry cannot be fully responsible for driving the shift of plastic use and disposal in Aotearoa New Zealand – brand owners and importers will need to demand change from international plastics manufacturers or suppliers as well. Plastics manufacturers are somewhat restricted in their product development by brand owners, but do have the opportunity influence decisions and work with brands to develop more sustainable solutions.

Practices by the plastics manufacturing industry that could support transformation in plastic use and disposal include:

- Ensuring plastic doesn't leak into the environment during logistics and manufacturing (see Case Study 2.4.11)
- Supporting businesses to shift to more sustainable plastics (see Section 3.7)
- Reducing the use of colour or other additives that reduce the practicality of a product being recycled
- Establishing new manufacturing processes to incorporate recycled plastics into new products (see Section 3.6.13).

[133] Eunomia Research & Consulting Ltd, "Investigating Options for Reducing Releases in the Aquatic Environment of Microplastics Emitted by Products", 2018

2.4.11 Case study: Operation Clean Sweep

Plastic pellets, or nurdles, are the raw material of the plastics manufacturing industry. They are commonly found in beach and river clean ups (see Figure 19). The plastic manufacturing industry in Aotearoa New Zealand identified this as a key issue for their members to address.

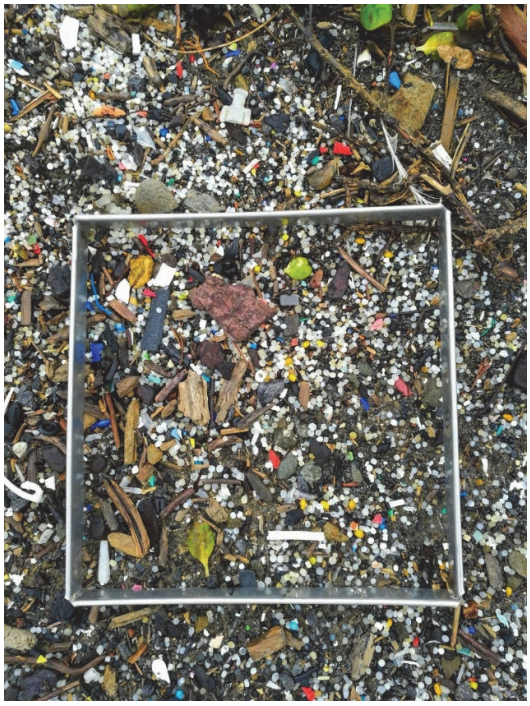


Figure 19 Plastic pellets used to manufacture plastic products washed up at Evans Bay, Wellington. Operation Clean Sweep® puts measures in place to prevent this leakage. Photo credit: Phil Clunies-Ross

Recognising that problems in current practices meant that plastic was leaking into the environment, the industry decided to implement Operation Clean Sweep® – the international best-practice guidance for the plastics industry that is designed to prevent the flow of plastics to the environment. The aim is zero pellet, flake or powder loss to our waterways.

Local implementation of this global initiative has been driven by the plastics industry body, Plastics NZ, since 2015.[134] Rather than just allow companies to sign up and commit to following best practice, Plastics NZ were the first in the world to implement an audit program for Operation Clean Sweep®. Companies are required to demonstrate that they have the correct measures in place to prevent pellet, flake and powder loss before they are considered compliant. So far, 87 companies have been audited, and 66 of those have achieved best practice in stormwater protection, out of roughly 300 plastics companies.[135]

The industry is aiming for all local plastics manufacturers to gain accreditation to prevent plastic loss to the environment. The next step is work with the freight industry to ensure that measures are in place to prevent leakage at all points of the supply chain.

A similar approach could be taken in other industries where environmental leakage of plastics is known to be a problem, such as construction and fisheries.

[134] More information available at: http://www.plastics.org.nz/environment/marine-litter/operation-clean-sweep
[135] See: https://www.plastics.org.nz/doing-business-in-nz/new-zealand-industry/general-statistics

2.4.12 Summary and opportunities for sector-led approaches

Sector-led action on rethinking plastics has the potential to drive a collective solution at scale and with pace. The packaging sector is making some headway, but regulatory levers could be used to ensure that best practice becomes standard practice so that progressive companies are not disadvantaged against competitors that refuse to change. Creating a system that supports businesses to rethink their packaging is covered in recommendation 4.

The fisheries, agriculture, construction and textile industries are examples of sectors that would benefit from a sector-wide approach to reducing their impact on the environment caused by plastics. Government could work with these industries to facilitate action and use regulatory frameworks to ensure best practice becomes standard practice. These are captured in recommendations within recommendation 4.

The local plastics manufacturing industry need support from government to shift to more sustainable use of plastics, which will be a demand from sector-wide changes in packaging, construction and agriculture, and a regulatory framework to reduce environmental impacts currently associated with the industry. These are captured within recommendations 4 and 6.

REGULATORY LEVERS COULD BE USED TO ENSURE THAT BEST PRACTICE BECOMES STANDARD PRACTICE SO THAT LEADING COMPANIES ARE NOT DISADVANTAGED AGAINST COMPETITORS THAT REFUSE TO CHANGE

Key considerations for implementing these recommendations:

Packaging

- The co-regulatory, not-for-profit Australian Packaging Covenant Organisation (APCO) partners with government and industry to reduce the impacts of packaging on the environment and is a successful model that Aotearoa New Zealand could replicate.[136]
- WRAP UK provides exemplary industry guidance and sector-specific action plans that could be drawn on and connected to by Aotearoa New Zealand's sector groups.[137]

Fisheries

- Local policies and solutions should build on Aotearoa New Zealand's existing international commitments and workstreams e.g. the International Maritime Organisation Action Plan (see Table 1).
- The Government's Aquaculture Strategy to 2025, released in September 2019, indicates that the Ministry for Primary Industries will work with the aquaculture sector to 'foster connections with other primary sectors to share and partner innovations in packaging, processing and transportation' to reduce waste. Because many companies are involved in both fishing and aquaculture, this work could be built on by the fisheries industry.

Agriculture

- Learnings from the successful accredited product stewardship schemes Agrecovery and Plasback could be taken and built on for new agricultural product stewardship schemes.
- Organisations such as Callaghan Innovation can facilitate connections between sectors and researchers to develop solutions to meet a specific need (see Case Study 3.7.2).

[136] More information available at: https://www.packagingcovenant.org.au/
[137] More information available at: http://www.wrap.org.uk/content/the-uk-plastics-pact

Construction

- A formalised and transparent accreditation or certification scheme for construction and demolition material waste companies could progress the work of the REBRI Certification led by Christchurch City Council.[138]
- Best-practice guidance could build on existing guidelines for construction and demolition waste, including:
  - Best-practice guidelines developed by the Ministry for the Environment in collaboration with local government[139]
  - Detailed guidance on minimising waste and REBRI from BRANZ[140]
  - Best-practice storage and handling guidelines for expanded polystyrene (EPS) developed by Plastics NZ.
- Sustainable use of plastics could be integrated into existing tools and environmental rating schemes (e.g. EnviroMark, Homestar, and Green Star).
- Existing voluntary product stewardship schemes in the sector (e.g. those for PVC (#3) pipes) could be scaled-up, accredited and/or mandated, and other schemes could be developed for other materials (e.g. building shrink wrap).
- Lessons could be learned from Operation Clean Sweep® (see Case Study 2.4.11) to design and implement an accreditation scheme to reduce environmental leakage on site.
- Determining whether to phase-out or restrict the use of certain problematic products (e.g. artificial grass which is known to shed microplastics) could be coupled with connecting to researchers and innovators to develop sustainable alternatives.

Textiles

- Efforts should be aligned to those led by the Ellen MacArthur Foundation on a circular economy for textiles and support moves to a shift to more sustainable fabric use (including wool).
- Local brands could align targets to the 'Fashion Pact' launched at the G7 Summit in Biarritz in October 2019 and signed by several large fashion brands, which includes a series of targets related to use and pollution of plastics.[141] Local retailers could support brands that have agreed to these targets.

Plastics manufacturers

- Scion's Roadmap for a New Plastics Economy is working with the local plastics industry to determine a pathway to a circular economy for plastics, with a focus on the shift to bio-based feedstocks for plastic.
- As the industry body for plastics manufacturers, Plastics NZ could help guide sector-specific approaches.
- A requirement for manufacturers of plastic (in conjunction with brands/retailers) to demonstrate that there is a known end-of-life solution for the product being manufactured could contribute to more sustainable use of plastics.

[138] More information available at: https://ccc.govt.nz/environment/sustainability/target-sustainability/services/commercial-building-design-consultancy/
[139] More information available at:http://www.cmnzl.co.nz/assets/sm/2260/61/057-INGLISMahara.pdf
[140] More information available at:https://www.branz.co.nz/minimising-waste and https://www.branz.co.nz/cms_display.php?sn=293andst=1
[141] More information available at:https://keringcorporate.dam.kering.com/m/1c2acf6f32f1c321/original/Fashion-Pact_G7_EN.pdf

2.5 Business-led action

All companies, from micro-businesses to SMEs through to multinationals, have a significant role in changing the way plastic is utilised in production, distribution and consumer use. Aotearoa New Zealand businesses can and should be at the forefront of this change. Businesses can lead the shift to a culture where considering the full life cycle impacts of a product is carried out in the design phase and taking responsibility or making provisions to support the management of their product at its end-of-life are strategic imperatives. To make informed decisions and changes based on the evidence, businesses require high-quality and accessible information, data and decision-support tools. A worst-case scenario is, for example, consumer push-back about plastic packaging triggering a product redesign to a non-plastic alternative that is actually less recyclable in our local context or has more detrimental environmental impacts. Ensuring appropriate processes are in place for sourcing, manufacture, distribution and returns/recycling, will put businesses at the forefront of initiatives that reduce the amount of plastic lost from the economy as waste. Secondly, it affords individuals more choice as to the action they can take to reduce their own environmental footprint.

Already, Aotearoa New Zealand is home to a growing cohort of forward-thinking businesses that have adapted their business models to challenge the current ways they use plastic in product design and throughout the supply chain. These businesses demonstrate that operating in a sustainable way and being more circular in their approach to plastic management can be a source of advantage. Spurred by a global trend, there is a growing momentum among the wider business community to change their relationship with plastics. Businesses must actively consider the long-term consequences of their operations and initiate strategies that will reduce the amount of packaging waste in our lands and oceans. The question arises as to what business infrastructure, initiatives and incentives would support more companies to do so. We can learn from the experiences of those businesses at the cutting-edge by recognising ways of managing the plastic value chain that are a source of improving performance and advantage, and removing the barriers that currently slow or prevent change.

Perhaps most importantly, those businesses at the forefront of innovation and transformative change around plastic use should be acknowledged as positive change-makers and success stories shared. We can take inspiration and insight from mātauranga Māori and Pasifika success stories, which align with circular economy innovations that scale, to support change that is global in reach and local in character.[142] Best practice in management of the plastic value chain needs to become standard practice. For example, if one company can demonstrate use of a more sustainable plastic for a particular application, without loss of functionality, quality or aesthetics, then regulatory levers could be in place that can drive other businesses to follow suit. Initially this might be encouraged by ensuring the users of existing plastics are confronted with the full-life costs of that material, including its disposal. This would help to make pricing more transparent so that bio-benign alternatives can compete and gain market share, since it would be expected these materials would become cheaper as demand rose.

[142] Illes, "What the World Can Learn from Māori Thinking", *Medium*, 29 May 2019

2.5.1 Transformative action business can take, with local examples

Tables 4, 5 and 6 list examples of actions that businesses can take that will support the system-wide cultural transformation behind rethinking plastics. Many of our recommendations aim to lower or remove the barriers listed for businesses. The points below are evidence of industry-led transformative action driving positive change in regards to Aotearoa New Zealand industry's relationship with plastics. Some businesses are taking responsibility for their impact on our environment, and also recognising that taking action can result in added value and improved productivity. This is not an exhaustive list, but highlights approaches that may be applicable for other businesses alongside examples that will help steer us towards a new plastics economy. Further details about the innovations driving some of these actions follow in Chapter 3.

Market-facing initiatives

Actions businesses might take that have public benefits and/or marketing advantages, including communication, branding and education of consumers.

Table 4 Market-facing actions that businesses could take to support rethinking plastics

Action	How it helps	Examples	Barriers
Make declarations and set targets about reducing non-renewable plastic production and waste	Sets the goalposts for business Branding Image Goodwill Raising awareness	Multinational and local businesses have signed the NZ Plastic Packaging Declaration[143] and/or the New Plastics Economy Global Commitment,[144] pledging to use 100% reusable, recyclable or compostable packaging in NZ operations by 2025	Current infrastructure limitations in NZ may limit some company's willingness to make these commitments (e.g. switching to compostable when there are insufficient facilities to manage waste)
Publicly disclose data on plastic production, use and waste (audit current use and forecast to 2025 and beyond)	Potential to contribute to aggregated national data to inform infrastructure planning Provides better data to support business planning	Some companies have publicly disclosed annual plastic packaging volumes as a total tonnage value, as part of the New Plastics Economy Global Commitment[145]	Commercial sensitivities Lack of framework to guide data collection
Commit to gaining industry certification or accreditation for environmental best practice	Illustrates best-practice targets Identifies feasible performance metrics	Various certifications exist e.g. Cradle to cradle,[146] EnviroMark,[147] and ISO14001[148]	Cost and feasibility may be prohibitive Availability varies between industries

[143] The New Zealand Plastic Packaging Declaration of June 2018 was a pledge by 12 multinational and several local businesses to use 100% reusable, recyclable or compostable packaging in NZ operations by 2025.
[144] The New Plastics Economy Global Commitment is led by the Ellen MacArthur Foundation in collaboration with the UN Environment and has been signed by the Ministry for the Environment and many multinationals More information is available at: https://newplasticseconomy.org/projects/global-commitment
[145] Ellen MacArthur Foundation, "New Plastics Economy Global Commitment June 2019 Report", 2019
[146] https://www.c2ccertified.org/get-certified a product standard that incentivises continual improvements of product design and manufacture to reduce environmental impacts
[147] More information available at: https://www.enviro-mark.com/
[148] More information available at:https://www.iso.org/iso-14001-environmental-management.html

Action	How it helps	Examples	Barriers
Offer take-back schemes/ product stewardship for products	Provides a returns or recycling pathway for consumers to utilise Opportunity for potential product/process innovation	H&M will take back any clothing (including other brands) to manage at end-of-life through rewear, reuse or recycling	Infrastructure needed
Provide or facilitate reuse options	Reduces the need for packaging	Some stores such as Bin Inn provide a discount for bringing containers for bulk buy purchases Countdown and Foodstuffs now allow reusable containers where previously single-use packaging was used, e.g. in the deli For The Better Good developed a reuse system for water bottles (that are also compostable at end-of-life)[149]	Maintaining convenience of single-use Food safety issues
Switch to certified compostable plastic packaging and facilitate collection if industrially compostable	Maintains convenience of single-use Reduces waste to landfill Certification of product ensures it will compose as advertised Ensures compostable plastic ends up in appropriate facility at end-of-life For food packaging, may increase the amount of food waste collected	Certified compostable mailer bags by Compostic[150] or r3pack[151]	Lack of infrastructure, collection methods and standards for compostable plastics (see Case Study 2.5.3) High risk of contaminating PET (#1) recycling stream may outweigh benefits Increased emissions if ends up in landfill
Provide support to business and community groups wanting to take action to change current practices of plastic use	Sharing the responsibility Image Sponsorship	Plastic free events and conferences guides[152] Envision supports community groups and social enterprises taking action against plastic waste	Encouraging collaboration between community groups with scarce resources Ensuring support and advice aligns to national plan or direction

[149] More information available at:https://www.forthebettergood.com/
[150] More information available at: https://www.compostic.co.nz/
[151] More information available at:https://r3pack.co.nz/collections/compostable-courier-bags
[152] Examples of guidance available at: https://www.eventbrite.co.uk/blog/host-plastic-free-festival-ds00/ and https://www.csuohio.edu/sites/default/files/170781_GreenEventGuide_R5_Web_1.pdf

Operational actions

Actions taken by businesses that are targeting internal operational processes, such as manufacturing or services, with the intention of improving performance.

Table 5 Operational actions businesses could take to support rethinking plastics

Action	How it helps	Examples	Barriers
Redesign product or packaging to improve recyclability in NZ (speak to local MRFs and recyclers for guidance)	Reducing the volume of poor plastic recycling options	Coca-Cola is shifting from coloured to clear PET (#1) bottles for Sprite and L&P so that there is better chance of these being recycled because clear PET (#1) has a better end-market	Brands may face competing interests between needing to maintain brand properties and designing packaging for recyclability Lack of good practice guidance and consultative support for businesses for the local context (e.g. for product design, packaging, recycling)
Establish new business models based on reuse systems	Identifies innovative value proposition for plastic management	The Honest Eco offers a refill service for household products that doesn't rely on people taking their product to a physical store[153] Ecostore has refill stations (see Case Study 2.5.2) Numerous businesses have established borrowing/leasing systems for reusable coffee cups (see Case Study 2.8.2) Spout Alternatives are piloting a keg system for milk for cafes[154]	May need to invest in new technologies and R&D Cost-benefit analysis Feasibility studies Cost-barriers to uptake unless widely accessible (e.g. in supermarkets) and with price parity to single-use options
Create a product using recycled materials or products	Reduces demand for virgin materials	Critical Things is a social enterprise that makes furniture and homewares by upcycling plastic waste[155] Coca-Cola is making all plastic bottles smaller than 1-litre and all water bottles from 100% recycled content[156]	Quality and availability of recycled content Food-safety issues if used in food packaging Virgin plastic can be cheaper than recycled plastic Infrastructure in NZ not currently sufficient to provide 100% food grade rPET (#1) so materials must be imported
Remove single-use plastic items from offering	Reduce circulation of single-use plastic	Air New Zealand is removing nearly 55 million single-use plastic items from its operation[157]	Maintaining convenience and efficiency Possibility of substitution having worse environmental impacts

[153] More information available at:https://www.thehonesteco.nz/
[154] More information available at:https://www.spoutalternatives.com/
[155] More information available at:http://www.criticaldesign.nz/
[156] Coca-Cola, "Coca-Cola Oceania, Amatil Announce New Recycling Plan,"
[157] Air New Zealand, "Air New Zealand Doubles Down on Plastic Waste Reduction", press release, 8 July 2019, http://www.scoop.co.nz/stories/BU1907/S00194/air-new-zealand-doubles-down-on-plastic-waste-reduction.htm

Action	How it helps	Examples	Barriers
Engage with researchers to develop new materials or solutions	Can address particular pain points Can develop new uses for 'waste' material	Zespri and Scion collaborated with a NZ plastics processor to produce a product from a bioplastic and residual kiwifruit waste (see Case Study 3.7.2)	Business may need a 'quick fix' and can't wait for R&D developments which can take a long time Desire for off-the-shelf solutions Cost of research can be prohibitive as can the capital equipment required for commercialisation
Implement consistent and informative labelling on products (further detail in Section 3.6.2)	Inform and educate consumers, encouraging informed decisions	The Australasian Recycling Label (ARL) (see Case Study 3.6.3) Crunch and Flourish developed a digital 'packaging star' label to show the recyclability of a plastic product[158] GS1 system (see Case Study 5.5.3)	Fragmented recycling system precludes consistent labelling messaging Digital reach limited
Switch to a more sustainable alternative material	Reduce non-recyclable plastics in circulation	FriendlyPak compostable starch-based foam packing product as an alternative to EPS[159] Alto's recycled PET (#1) (rPET) meat tray developed for Foodstuffs is made of 50% recycled plastic and is 100% recyclable rather than alternatives such as PS[160] Sanford Ltd is shifting from expanded polystyrene trays for shipping seafood (not readily recyclable in NZ) to insulated cardboard[161]	Many brands are not equipped to investigate sustainability of material choices through standardised methods (e.g. LCA)
Collaborate and innovate with people outside own business for shared solutions	Open innovation	Te Ōhanga (based at Scion) supports circular collaboration between businesses and people in a workspace environment SBN brought companies together to chart a pathway to a circular plastic packaging system for NZ (see Case Study 2.4.2)	Non-willingness to share information with competitors Lack of incentives

[158] More information available at:https://www.crunchandflourish.com/
[159] More information available at: http://www.friendlypak.co.nz/
[160] More information available at: http://www.alto.co.nz/the-buzz
[161] More information available at: https://www.sanford.co.nz/assets/announcements/Sanford-Annual-Report-2018-web.pdf

Supply chain actions

Actions businesses can take in monitoring and managing their supply chains, with a longer-term goal of reimagining the supply chain.

Table 6 Actions related to the supply chain that businesses can take to support rethinking plastics

Action	How it helps	Examples	Barriers
Audit the supply chain to look for opportunities to reduce plastic use	Reduce plastic waste from circulation Ensures transparency of supply chain and availability of information/data	Supply chain databases (e.g. GS1) could be utilised for this (see Case Study 5.5.3)	Cost, feasibility and legitimacy of a supply chain audit can be difficult
Challenge suppliers/ customers to deliver/ demand packaging solutions that reduce waste or footprint in plastic usage	Provides opportunity for returnable transit packaging solutions Shifts use of problematic plastics to preferred plastics or alternative materials Removes from market Drives innovation or reuse	International examples: Walmart's 'sustainable packaging playbook' for its suppliers has detailed information about recyclability for each major packaging format (guidance, not compulsory)[162] Tesco pledged to ban brands that use excessive packaging,[163] after previously providing suppliers preferred materials list requirements[164] San Francisco Airport banned the sale of single-use plastic bottles[165]	Smaller retailers may not have the influence to demand high level of change NZ size of market may limit power to influence material change for large multinational companies
Shift to plastic sourced from renewable resources	Less reliance on non-renewable source of feedstock	Ecostore switched their packaging from recycled fossil-fuel based plastic to a bio-based plastic made from sugarcane (see Case Study 2.5.2)	Cost of switching to new resource Understanding the total cost of renewable resources (e.g. sugarcane is a water-intensive crop, sugarcane farming has also fuelled deforestation)
Prioritise collaborative relationships with supply chain partners who share the same commitments in regards to plastic	Leveraging resources Sharing knowledge Creating synergies throughout the supply chain	The Warehouse is working with its supply base to ensure its suppliers share the same standards[166]	Small retailers will find it difficult to shift larger supply chain partners Supply chain collaboration requires sharing of sensitive information

[162] More information available at:https://www.walmartsustainabilityhub.com/media-library/document/sustainable-packaging-playbook-deep-dive/_proxyDocument?id=00000169-15fc-dd5e-a3eb-75fc34d80000
[163] Jolly, "Tesco Promises to Ban Brands That Use Excessive Packaging", *The Guardian*, 22 August 2019
[164] More information available at https://sustainability.tescoplc.com/media/475659/tesco_preferred_materials_list_21112018.pdf
[165] Clayton, "San Francisco Airport Announces Ban on Sales of Plastic Water Bottles", *The Guardian*, 2 August 2019
[166] Flaws, "Time for Piecemeal Plastic Waste Solutions Has Passed, Says the Warehouse", *Stuff*, 28 July 2019

2.5.2 Case study: A business enabling people to rethink their use of plastic

Ecostore is an exemplar of how a business can take transformative action to rethink how we use plastics and inspire system-wide change.

To enable people to reduce their use of non-renewable single-use plastics, Ecostore:

- Shifted from fossil-based plastic to **plastic from a sustainable resource** – sugarcane – which is fully recyclable. Ecostore has published a detailed case study about their journey switching to sugar plastic.[167]
- **Incorporate post-consumer recycled (PCR) plastic into their products** – currently they use 50% PCR plastic in dish powder bottles and 10% PCR plastic in their two highest-volume products, laundry and dish liquid bottles, with plans to increase this over time.

Figure 20 A refill station where people can reuse bottles when buying new products.

- Provide refill stations to **enable people to reuse bottles** and have made these easier to access for more people by increasing the number of stations and expanding from green stores to mainstream supermarkets.[168]
- Is trialling a **closed-loop packaging return program** to take responsibility for their products at end-of-life. This creates high-quality recycling streams, which helps keep the resource in circulation.
- **Reduced the amount of plastic they use in bottles** by 15-18% for a number of their high volume products, therefore reducing the overall use of plastic for the same product and purchasing practices.
- **Made bottles from ocean plastics** to remove existing waste from our environment and reduce the resources and energy needed to create new packaging, and start a conversation about where plastic comes from and ultimately where it can end up.[169]

Other businesses rethinking their use of plastics can learn from their approach and experiences. Some actions that have helped Ecostore be able to achieve these changes are:

- **Prioritising a reduction in the environmental impact of their products:** By having this as a core value of the business, decisions don't rest solely on the cost of products or packaging, but are based on a longer-term view about the impacts of the whole life cycle of a product. This allowed the business to move to a renewable plastic with a higher raw material cost, over 5 years ago.
- **Making commitments and pledges:** As signatories of the Climate Leaders Coalition CEO's Climate Change Statement and the New Plastics Economy Global Commitment, the business has to measure and report on targets related to carbon footprint and plastic packaging use. This provides concrete goals to reach and can help galvanise change.
- **Considering a range of alternatives and why they may or may not work in our local context:** For example, Ecostore decided not switch to the compostable plastic (PLA) for several reasons, including the lack of commercial composting infrastructure to manage the waste and the risk that these products may contaminate recycling streams. This meant that the business made the switch to bio-based HDPE (#2) plastic four years after they initially scoped out a potential

[167] Full case study available at: https://www.climateleaderscoalition.org.nz/__data/assets/pdf_file/0019/159220/Ecostore-case-study.pdf
[168] At publication there were 60 stations located throughout Aotearoa New Zealand. For an up-to-date list of refill stations see http://www.ecostore.co.nz/refill-stations
[169] For more information see: https://ecostore.com/nz/limited-edition/

option, but that they were more confident their product was suitable for Aotearoa New Zealand when they did make the switch.

- **Educating their team about circular thinking:** Even though Ecostore has always been driven by sustainable and circular practices, they see it as essential that the whole team has a solid understanding of circular principles and how these drive innovation and business systems. Ecostore sought help from Circularity (a Kiwi circular strategy agency[170]) to embed understanding of circular principles within the business and wider team, and to explore what circular products and systems could become through a series of design sprints. This has helped to foster the business culture around rethinking use and disposal of plastics.
- **Working with like-minded businesses:** Ecostore partners with suppliers and retailers who implement sustainability initiatives and want to challenge the status quo. This has allowed the business to find a renewable source of plastic and provide over 60 refill stations for products throughout the country. They have also partnered with Danish packaging manufacturer, Pack Tech, who source ocean plastics to create packaging.
- **Recognising that a step-wise approach is needed.** Progress won't happen at the rate needed to mitigate plastic pollution if we wait for perfect solutions, so Ecostore is trialling a program to take the pressure off Aotearoa New Zealand's overwhelmed recycling system while the practices of reuse systems (e.g. product refills) become more habitual for people. Providing different solutions will help reduce waste to landfill as people become more familiar with new practices.
- **Seeing rethinking plastics an ongoing challenge:** The business doesn't stop once one improvement is made, but continues to think about ways to reduce the footprint of their products through packaging and manufacturing innovations. They also provide a range of options to suit the needs and preferences of different people.

[170] For more information see: https://www.circularity.co.nz/

2.5.3 Case study: New Zealand Post's quest for an alternative to plastic

The driver: New Zealand Post wants a more sustainable, environmentally friendly alternative to their existing plastic mailers (e.g. courier bags, pre-paid postage bags). New Zealand Post has also signed the New Zealand Plastic Packaging Declaration, committing to using 100% reusable, recyclable or compostable packaging by 2025.

The plan: In late 2017, New Zealand Post put out a request for information (RFI) for an alternative carrier pack material. Potential materials were assessed against value chain criteria as outlined in the Sustainable Business Council Value Chain Guide.[171]

The contenders: A range of options were submitted by suppliers, including compostable, biodegradable, materials with recycled content and oxo-degradable. When materials were assessed, initially compostable materials looked the most promising due to a number of factors, including apparent ease of end-of-life disposal, range of manufacturers and potential cost profile. A detailed request for proposal (RFP) was issued for a compostable carrier pack in early 2018. From further investigation of compostable material use in Aotearoa New Zealand, as well as information gathered through the RFP process, it became apparent that compostable plastic may not be a better option.

The issue: There are a number of barriers to the use of compostable plastic carriers in Aotearoa New Zealand at the time of New Zealand Post's assessment. Most commercial composting facilities will not accept compostable plastic film, and there is a lack of approved compostable adhesives and labels meaning the whole product cannot be composted (and it was unclear whether consumers could be relied on to remove the non-compostable components). There were no Aotearoa New Zealand-wide home compostable standards in use, although overseas standards were applied to some products. Leaving such packaging to mainly be composted in a home composting environment also raised concerns, including the accessibility to effective composting at home. Consumers who have no effective way to deal with compostable plastic may treat the carriers like current non-compostable packing and possibly contaminate soft plastic recycling streams. Compostable plastic requires a specific composting environment in order for it to be able to break down and fully return to nature. Without these conditions, their environmental benefits over a non-compostable product are debatable.

The decision: As part of their assessment process, a survey of 1000 New Zealanders was undertaken – 66% said they would prefer a compostable product over a traditional plastic one and thought it was better for the environment. But the lack of infrastructure and consumer awareness around the complexities of compostable plastic made the New Zealand Post team feel that to offer this product at this time would be greenwashing and not a responsible business decision.

The outcome: New Zealand Post continues to explore alternatives to current carrier packs. Shortcomings in soft plastic recycling infrastructure in New Zealand, including recent changes to the soft plastics recycling scheme, need to be addressed when considering the feasibility of alternative packaging. In light of this work, New Zealand Post has put out a set of sustainable packaging guidelines to guide the development of parcel packaging to fit the circular economy model and are keeping their website up-to-date with progress.[172]

[171] More information available at: http://www.sbcvaluechain.org.nz/
[172] More information available at: https://www.nzpost.co.nz/sites/default/files/uploads/shared/packaging-design-principles.pdf and https://www.nzpost.co.nz/about-us/sustainability/sustainable-packaging

2.5.4 Summary and opportunities for business-led action

The competitive nature of the business sector makes it difficult to ensure widespread uptake of responsible plastic use without backing from legislation and sector-wide approaches (as discussed in Section 2.4). Most businesses, particularly small-to-medium enterprises, struggle to navigate the complexities around sustainable use of plastics. Government guidance and action is crucial to enable all companies to adopt best practices and will be fundamental to rethinking plastics, including addressing barriers currently faced by business, which is captured in recommendations 4 and 5.

Key considerations for implementing these recommendations:

- Best practice guidance for packaging could build on and localise existing efforts such as the UK WRAP's Rigid Plastic Packaging Design Tips for Recycling,[173] the Packaging NZ Code of Practice[174] and the US Sustainable Packaging Coalition's Design for Recycled Content guide.[175]
- Support could be strengthened by the establishment of a group that provides advice through consultation during packaging design.
- The Circular Economy lab in Queensland has been a successful 'sandbox environment' to encourage businesses to collaborate and be creative about shifting to circular economy which could be modelled from.[176] Part of the success comes from starting small with closed systems, before scaling up.
- Aligning materials requirements with Australia could strengthen case for multinational brands.

[173] More information available at: http://www.wrap.org.uk/sites/files/wrap/Design%20tips%20for%20making%20rigid%20plastic%20packaging%20more%20recyclable.pdf
[174] More information available at: http://www.packaging.org.nz/page/15/code-of-practice
[175] More information available at: https://recycledcontent.org/
[176] More information available at: https://circularecolab.com/

2.6 Community-led action

Community groups, not-for-profit (NFP) organisations, non-governmental organisations (NGOs) and charities are at the heart of action against plastic pollution. Community groups have traditionally played a strong role in leading environmental initiatives. They are particularly good at leading place-based action that brings together people to protect or enhance a particular ecosystem (such as a river, beach front, park or forest), or to build environmentally responsible norms within a community. For example, before the single-use plastic shopping bag ban was legislated, several community groups launched initiatives and programmes to encourage their community to move to using reusable alternatives, since as far back as 2005.[177] As this example demonstrates, community action can instigate changes in consumption and business behaviour that can produce positive change on a much larger scale. Enduring change will stem from behaviour change.

2.6.1 Local initiatives and ongoing efforts

There are many community initiatives aiming to tackle plastic waste and pollution throughout Aotearoa New Zealand. In Table 7 we highlight some community groups and projects that are leading by example.

Table 7 Community initiatives throughout Aotearoa New Zealand leading the way in tackling plastic waste and pollution

Initiative	Details	Location	Maturity	Scalability
Larger national NGOs/NFPs				
Sustainable Coastlines	NGO that established a citizen science beach litter monitoring program (litter intelligence), provides resources and information to support people to take action to prevent litter (see Case Study 5.9.4) [178]	Nationwide	Growing (since 2011)	Scalable with new volunteers and citizen scientists
Aotearoa Plastic Pollution Alliance	A collaborative forum of researchers, educators, scientists, industry and conservationists working to mitigate and prevent plastic-related pollution in Aotearoa and Oceania[179]	Nationwide	Young	Potential to grow with increasing collaboration between groups
Sea Cleaners	Trust that coordinates volunteers to help with coastal clean-ups and educates the public about how to prevent marine pollution[180]	Auckland and Northland	Mature (since 2002)	Could expand to other regions with more resource

[177] Golden Bay, "Golden Bay 1st Community to Be Free of Plastic Bags", press release, 3 January 2005, http://www.scoop.co.nz/stories/AK0501/S00002/goldenbay-1st-community-to-be-free-of-plastic-bags.htm
[178] More information available at: http://sustainablecoastlines.org/ and https://litterintelligence.org/
[179] More information available at: http://www.nzappa.org/
[180] More information available at: https://seacleaners.com/

Initiative	Details	Location	Maturity	Scalability
Keep New Zealand Beautiful	NFP that provides public education to reduce litter through national campaigns, supports volunteer clean-ups, and undertakes research. Also runs the KNZB award[181]	Nationwide	Mature (since 1967)	Well established in NZ and connected internationally
Greenpeace	Local arm of global organisation that takes action on plastic waste through public-facing information, supporting campaigns, petitions, and writing policy papers[182]	Nationwide	Mature	Well established in NZ and connected internationally
Zero Waste Network	Network of community enterprises that support the zero waste movement[183]	Connects regions across NZ	Mature	Can support knowledge sharing between groups with common goals across different regions
Para Kore	Supports marae and other groups to become zero waste (see Case Study 2.6.2)[184]	North Island, expanding to South Island	Mature (since 2009), but growing	Scalable nationwide pending resourcing
Ghost Fishing NZ	Local arm of international organisation who remove lost fishing gear and other waste from harbours and the ocean through diving[185]	Nationwide	Growing (since 2015)	Growing in NZ and connected internationally
Smaller local community groups/initiatives				
Golden Bay Plastic Bag Free	The first community initiative in NZ to go plastic shopping bag free in 2005	Golden Bay	Mature	Now national regulation enforces this
Newtown Community and Cultural Centre Wash Against Waste	A hireable community resource containing cutlery, crockery and napkins that can be borrowed by the public[186]	Wellington	Mature	Other community groups could replicate this – e.g. Timebank Raglan has a similar initiative
Palmy's Plastic Pollution Challenge	Citizen science project between Environment Network Manawatu and Massey University to measure litter from urban streams[187]	Palmerston North	Young	Could expand or connect with other regional efforts and align data collection with Sustainable Coastlines methods, which are accredited Tier 1 measures

[181] More information available at: https://www.knzb.org.nz/
[182] More information available at: https://www.greenpeace.org/new-zealand/
[183] More information available at: http://zerowaste.co.nz/
[184] More information available at: http://parakore.maori.nz/
[185] More information available at: https://www.ghostfishingG.co.nz/
[186] More information available at: http://www.newtowncommunity.org.nz/washagainstwaste.html
[187] More information available at: https://enm.org.nz/about/palmy-plastic-challenge

Initiative	Details	Location	Maturity	Scalability
F.O.R.C.E (For Our Real Clean Environment)	Organises monthly litter clean-up events[188]	Whangārei	Young (formed mid 2018)	Scalable with potential to begin tracking litter data
Love Kaipara	Run school and community-based education programmes on waste minimisation and offer site visits and waste audits for businesses to reduce waste[189]	Kaipara	Since 2016	Learnings could be shared with other groups
Kaipatiki Project	Offers educational events for community groups and schools on sustainability, including recycling and using more sustainable resources (e.g. harakeke) [190]	Kaipatiki	Mature	Learnings could be shared with other groups
EcoMatters	Shares knowledge and tools to support the community to reduce waste[191]	Auckland	Mature	A model that could be adopted by other local communities
Sustainable Whanganui (including Plastic Free Whanganui)	Community trust that has a physical resource library, runs community projects and events, and provides online resources, including reducing plastic use[192]	Whanganui	Mature	Learnings could be shared with other groups
The Rubbish Trip	Offers presentations to community groups, schools, businesses and households about reducing rubbish. Also provides regional guides for low-waste option shops, cafes etc.[193]	Toured around the country and online resources	Since 2015	Can reach more people with more touring and growing library of regional guides
RefillNZ	Initiative that shows a cafe or restaurant is happy to fill up your reusable water bottle to support the practice of reuse and avoid single-use plastic drinks bottles[194]	Nationwide	Scaling up	Can grow throughout the country

[188] More information available at: https://www.force.org.nz/
[189] More information available at: https://www.lovekaipara.co.nz/
[190] More information available at: http://kaipatiki.org.nz/
[191] More information available at: https://www.ecomatters.org.nz/
[192] More information available at: https://sustainablewhanganui.org.nz/
[193] More information available at: http://therubbishtrip.co.nz/
[194] More information available at: https://refillnz.org.nz/

2.6.2 Case study: Para Kore – helping people reduce their waste

Para Kore is a Māori organisation that provides mentoring and support for marae, kōhanga reo, kura, community organisations, iwi, tertiary, commercial sector, events and Māori communities to reduce their waste.[195]

The goal of becoming para kore (zero waste) is based on circular economy principles. The educational programme teaches whānau to reuse materials, sort waste properly, recycle and compost, and most importantly, to plan ahead for how they will manage waste so that as little as possible is generated and sent to landfill.

Figure 21 Taeya Ririnui, 4, Tuara Rahiri, 6, and Hemanawa Ngatoko-Hawkins, 8, at the Huria Marae, one of the first marae to sign up to the Para Kore programme. Photo credit: Tracy Hardy.

The challenges of dealing with waste on a marae

Dealing with waste generated on a marae comes with unique challenges. For example, the responsibility rests on volunteers, meetings may be irregular and have different people coming and going, and there is generally no funding for waste management.

Because of these challenges, the systems that have been shown to be successful to reduce waste on marae are likely to also be successful in other settings such as schools and businesses, where some of those barriers are not present (i.e. the same people consistently attend and there may be more resources available). Para Kore started with educating marae groups, but the format has since proven successful with schools and other organisations as well. Of the roughly 330 groups supported by Para Kore, around half are marae and the rest are other organisations.

Learnings from Para Kore could be shared with other community groups around Aotearoa New Zealand.

What can be learned from Para Kore's success?

Getting buy-in from leaders and making sure waste reduction is on the agenda is key. Para Kore meet groups in person and normally present to the marae committee in the first instance to establish waste management as a priority and to form the relationship.

The marae need to nominate an internal person who will champion the movement. Supporting the wider group to transform their usual practices will take time and effort, so ensuring there is someone to lead by example and keep up encouragement is important.

Para Kore continues to strengthen their relationship with ongoing support. After providing the initial information and training, the regional advisor generally checks in each year with the group. This is made possible by the organisational structure where a group of regional advisors based around the country are centrally managed. Having this set-up also allows for shared resources and consistent systems and teaching across the country.

[195] More information available at: http://parakore.maori.nz/index.php/

They also offer support to get the message to a broader group by delivering wānanga to whānau. This may be through the Para Kore team presenting at a larger hui, or by sharing teaching resources so that the group can lead this education piece themselves.

At the beginning, Para Kore do a waste audit to understand current amounts and types of waste being produced, and what systems should be established to move towards zero waste. They also provide a way to track waste, so that the group can measure their improvements. This works to make the efforts seem tangible and also provides a basis for ongoing improvement by showing where next steps could be taken.

In addition to providing resources and information, Para Kore physically help establish the systems for recycling and composting that will enable the marae to do the right thing with their waste. One of the most important parts of the physical set up is ensuring that there are clear labels that explain what goes in each different bin. Para Kore has also worked with WasteMINZ to develop te reo Māori translations for rubbish and recycling bin labelling that are available to be used anywhere.[196]

Room to grow

Para Kore was officially launched in 2009. During the past 10 years, over 220,000 people have attended presentations, wānanga and events hosted by the organisation. Almost all of the groups that have been through the Para Kore programme have been in the North Island, with only a couple in the top of the South Island on board. There is plenty of room for the programme to expand its teachings further if resourced to do so.

[196] More information available at: https://www.wasteminz.org.nz/sector-groups/behaviour-change/te-reo-maori-resources-for-waste-minimisation/

2.6.3 Case study: Plastic Bag Free Raglan, Pēke Kirihou Kore Whāingaroa

In October 2018, Whāingaroa Raglan won the Keep New Zealand Beautiful 'Community Environmental Initiative Award'. The kōrero behind the Award was a story of what happened when a whole community worked together to engage in significant behaviour change around one troublesome item of waste – single-use plastic carry bags.

Plastic Bag Free Raglan has summarised their experiences, lessons learned and the methodologies employed in a very detailed case study that gives advice to other community groups setting out on a similar journey.[197] Below we pull out the key insights highlighted in the report as instrumental to the project's success.

Figure 22 The reusable bags that were gifted to support the movement to becoming plastic-bag free. Photo credit: raglan.net.nz

- **Research:** Understanding the problem and possible solutions and learning from similar experiences of other groups throughout the world prevents 'reinventing the wheel' and helps solve the problem in question more efficiently.
- **Leadership:** A strong group of people leading the project ensures it is enduring through difficult times.
- **Team:** A high functioning, capable and empowered working team working under the guidance of strong leadership is instrumental to success.
- **Resources:** Financial support is crucial for a project to flourish.
- **Engaging mission:** A simple, easy-to-remember, powerful statement helps with community buy-in.
- **Data:** Local data helps to engage the specific community by making it a real and tangible local issue and baseline data provides a vital benchmark for the project for later comparison.
- **Key behaviour change strategies:** Understanding what it is that will tap into peoples' motivation to change and implementing strategies related to these will improve uptake.
- **Excellent and consistent positive messaging:** Communication that is regular, simple and consistent with the theme will resonate more clearly with people. Positive messaging is more effective than messaging that invokes fear.
- **Tenacity and determination:** During times when you need to dig deep, reminders of why you started on the journey and what the community's vision is can help to reignite enthusiasm.

> "Planning, hard work, tenacity and community coming together has resulted in an excess of 240,000 single-use plastic bags being saved from entering the Raglan environment or landfill in the space of one year. Nationally, New Zealanders across the country let the Ministry for the Environment know there was support for a total bag ban, which is in effect from 1 July 2019. While we can't know the extent to which Plastic Bag Free Raglan helped to instigate this ban, there is no doubt the mahi undertaken in little Raglan helped put the wheels in motion. Seeing positive results has created hope and has encouraged the momentum to grow. Now the battle to rid our town of single-use plastic has evolved in Raglan to look at the next topic to take on."

[197] The full case study is available at: http://whaingaroa.org.nz/wp-content/uploads/2019/06/pbfr_2019_casestudy-FINAL-WEB.pdf

2.6.4 Actions that community groups can take

Community groups can be small localised approaches through to NGOs that foster international linkages. Across these groups, actions and approaches that will help community initiatives take hold include:

- Connecting with community residents as neighbours, rather than as representatives of an institution.
- Engaging with local schools or existing community initiatives or NGOs to establish a local arm (e.g. Para Kore).
- Using clean-up efforts as an opportunity to collect data (and standardise this nationwide) – see Sustainable Coastlines as an exemplar (see Case Study 5.9.4).
- Sharing successful community initiatives to inspire other community groups.
- Going plastic free for events or conferences (an Australian marine science conference detailed their experience of going plastic-free for The Conversation[198]).
- Raising awareness of the issues around plastic pollution and educating the community about new practices to minimise these issues.

2.6.5 Barriers and hurdles to action

- Community initiatives may have limited funding and rely on volunteers.
- Community groups may be short-lived and have limited reach, unless able to partner with government, schools or businesses.
- Without funding and reach, it is hard to share learnings and leverage resources that have been developed.
- A poor understanding of baseline attitudes may make it difficult to understand what approaches are more or less effective.

2.6.6 Summary and opportunities

Community groups need to be supported to continue to lead local environmental initiatives related to plastics and sustainability and share their successful initiatives further afield. This is addressed within recommendation 5.

Key considerations for implementing these recommendations:

- Engagement with successful community initiatives could help government understand what barriers could be removed to help community projects related to plastics succeed.
- Ensuring that any funding related to plastic is accessible for community groups could help the grassroots and localised initiatives that lead to wider change.

[198] Elizabeth Sinclair, "We Organised a Conference for 570 People without Using Plastic. Here's How It Went", *The Conversation*, 10 July 2019

2.7 Initiating changes through education

Education is a critical lever for cultural transformation. There are many opportunities for rich, in-depth and ongoing learning and action across the education sector. Within this context, we can inspire and develop a new generation of people who practice kaitiakitanga. Children and young adults can learn to take action and can share their new practices with whānau, friends and wider communities. This has potential to help these practices become a new norm embedded within communities, and society more broadly.

We know that school is where many students learn about environmental issues, so it is critical to ensure these learning experiences are effective at empowering students to take action and support cultural transformation towards a holistic approach to living sustainably.[199]

For education to effectively support this cultural transformation, we need:

- A curriculum framework that supports teaching environmental and sustainability education
- Schools that foster a culture of sustainability and environmental protection
- Teachers to be capable and equipped to teach environmental education through engaging and interesting formats that not only raise awareness of environmental issues, but support students to develop the dispositions and skills needed to take action.

The New Zealand Curriculum provides a broad framework for guiding each school and kura to develop their own localised curriculum. Although environmental education, education for sustainability, and environmental education for sustainability[200] are not mandated learning areas, the curriculum nonetheless encourages a focus in these areas. For example, two of the values to be encouraged in whole-school curriculum development are community and participation for the common good, and ecological sustainability, which includes care for the environment. Similarly, a key principle underpinning school curricula is that the curriculum has a future focus, encouraging students to 'look to the future by exploring such significant future-focused issues as sustainability [and] citizenship…'[201] In addition, the current framework is well-suited for plastics to provide a rich and meaningful context for cross-curricular learning through science, technology, social studies, sustainability and mātauranga Māori.

The individual school environment also plays a significant role in cultural transformation. A school-wide commitment to issues of sustainability can provide tangible opportunities for students to take meaningful action and therefore foster a sense of empowerment, rather than risking a sense of disempowerment associated with the size of the problem. This is illustrated in Case Study 2.7.2 which outlines the Te Aho Tū Roa or Enviroschools programmes, contributed by Heidi Mardon. School prioritisation of environmental and sustainability issues also strengthens the impact of individual teachers' lessons and actions. School staff can lead by example and support students on the path to developing new routines and habits,[202] with the goal of making these behaviours the social norm within the school.[203]

Teachers' confidence and ability to teach broader themes around the environment and sustainability is a prerequisite to improving students' understanding of these areas. Without being mandated in the curriculum, the level of coverage varies between teachers based on individual or departmental views and commitments. This is particularly variable at primary school where teachers are typically generalists. Aotearoa New Zealand's teachers are adept at developing content – however, low scientific knowledge and scientific literacy[204] among our teachers (compared to other countries)

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[199] Ministry of Education, "He Whakaaro, Educational Insights: How Environmentally Aware Are New Zealand Students? ", 2019
[200] Department of Conservation, "Mātauranga Whakauka Taiao, Environmental Education for Sustainability", 2017
[201] Ministry of Education. 2007. The New Zealand Curriculum. Wellington, NZ: Author. p. 9
[202] Darnton, A, Verplanken, B, White, P and Whitmarsh, L. (2011). *Habits, routines and sustainable lifestyles: summary report.* AD Research and Analysis for DEFRA, London.
[203] Long, J., Harré, N. and Atkinson, Q. D. (2014). Understanding change in recycling and littering behavior across a school social network. *American Journal of Community Psychology, 53*(3-4), 462-474.
[204] Knowledge and understanding of scientific concepts and processes to provide a context for addressing problems and support decision making.

may prevent teachers from making science the focus of that content. In order to make the most of education as an avenue for cultural transformation for how we use plastic, we need to support our teachers with resources and sustained professional learning and development to build confidence in teaching environmental education and education for sustainability, in a holistic way that includes scientific, social and te ao Māori perspectives.[205]

There are already numerous resources available to support teachers to do this (see Table 8 for examples related to plastics). Raising the profile of existing resources and making it easier for teachers to access and utilise them, in particular by aligning them to the curriculum, will help to increase uptake and effectiveness of the resources. The Science Learning Hub has already done this for some plastics resources (see Appendix 2).[206]

Effort could be made to use engaging formats at school to improve the effectiveness of teaching these environmental issues and science more broadly. Students who engaged in science-related activities (but not students who had higher interest in science) were significantly more optimistic about the environment, suggesting engagement is particularly important for 'wicked problems' such as plastic that can lead to pessimism. Examples of engaging learning formats include:

- Game-based learning[207] through digital[208] or non-digital platforms: For example, a school-based litter reduction study that used a game to assess how students would be motivated not to litter found that linking the issue of litter with possible downstream effects (by offering to donate money to support an endangered marine animal) improved motivation among students by adding a moral dimension to the issue.
- Citizen science: Online citizen science can connect students with projects and data that they would not otherwise be able to access.

Improving education about, in and for the environment has the potential to inspire and empower the next generation to practice kaitiakitanga (see Section 1.3.1) by supporting students to develop their action competence.[209]

Tertiary education also provides opportunities for learning and action and supports a wider shift in society through leadership and research. In addition to the function as a critic and conscience of society, universities contribute to the body of research across science, engineering and social change policy that provides the evidence to inform efforts to rethink plastics (see Table 9). Within a university setting, there is opportunity to build a platform to support changing practices. For example, Aotearoa New Zealand universities ranked highly in the global impact rankings by Times Higher Education on how universities are performing against the UNSDGs (described in Section 1.2.1).[210] This provides a fantastic platform to adopt and build on rethinking plastics – universities could have a collaborative discussion to share their teaching and research on plastics and consider how to progress these ideas collectively.

[205] Ernst, J., and Erickson, D.M. (2018). Environmental education professional development for teachers: A study of the impact and influence of mentoring. The Journal of Environmental Education, 49:5, 357-374, DOI: 10.1080/00958964.2018.1451813
[206] More information available at: https://www.sciencelearn.org.nz/
[207] Jabbar et al., "Gameplay Engagement and Learning in Game-Based Learning: A Systematic Review," *Review of Educational Research* 85, no. 4 (2015)
[208] Clark et al., "Digital Games, Design, and Learning: A Systematic Review and Meta-Analysis," *Review of Educational Research* 86, no. 1 (2016)
[209] Defined in this context as 'the ability to arrive at solutions for individual and societal problems through critical analysis of environmental issues'.
[210] For example, the University of Auckland ranked first in this assessment https://www.auckland.ac.nz/en/about-us/about-the-university/the-university/sustainability-and-environment/university-of-auckland-is-1st-in-global-university-impact-rankings.html

2.7.1 Local initiatives and ongoing efforts

There are already several established educational programmes that include plastics education, but there is plenty of room for these to scale and grow, become more widely adopted, and for additional programmes to be developed.

Table 8 Primary and secondary school initiatives related to plastics and sustainability

Initiative	Details	Location	Maturity	Scalability
Cross-curricular teaching materials developed to support the New Zealand curriculum	A range related to plastics, packaging and sustainability, e.g. 'All That Packaging!' resource from NZ maths and 'Transform – a visual arts based investigation of waste' for the Arts[211] The Connected Journals and School Journals also have relevant articles, e.g. 'Turning Old Into New' and 'The Plastic-free Challenge'[212]	Nationwide	Varied	Opportunity for further materials related to plastics Existing resources could be highlighted to teachers
Curious Minds programme	Includes citizen science projects related to plastics e.g. 'Project Litter: tracking beach trash' and 'Can recycling help homelessness?'[213]	Various locations across NZ	Mature programme, projects varied	Most projects funded for localised applications but successful projects and data collection efforts could be scaled or replicated
Science Learning Hub	Provides an extensive range of educational resources related to plastics (e.g. What happens to our plastic bottles? Made in collaboration with Flight Plastics) – see Appendix 2 for full list[214] The Futures Thinking Toolkit is designed to scaffold students' consideration of possible and preferable futures	Nationwide (online)	Mature	All accessible via the internet
Nanogirl Labs	Plastic education project[215]	Various locations across NZ	New	Reach and longevity of project likely to depend on funding
Toimata programmes (Te Aho Tū Roa and Enviroschools)	Teaches students about sustainability and environment issues using action-based learning (see Case Study 2.7.2)	Various locations across NZ	Mature	Room to grow

[211] See https://nzmaths.co.nz/resource/all-packaging and https://nzcurriculum.tki.org.nz/Curriculum-resources/Education-for-sustainability/Learning-experiences for examples

[212] See: http://instructionalseries.tki.org.nz/Instructional-Series/Connected/Connected-2017-Level-4-Where-to-Next and http://instructionalseries.tki.org.nz/Instructional-Series/School-Journal/School-Journal-Level-2-November-2018/The-Plastic-free-Challenge

[213] See: https://www.curiousminds.nz/

[214] See: https://www.sciencelearn.org.nz/

[215] More information available at: https://www.nanogirllabs.com/

Initiative	Details	Location	Maturity	Scalability
Para Kore	Teaches methods to help achieve zero waste for kōhanga reo, kura kaupapa, kindergartens and schools (see Case Study 2.6.2)[216]	Various locations across NZ (mostly North Island)	Mature	Scalable to further schools and South Island
Sustainable Coastlines	Delivers educational presentations to schools and can train others to be able to address plastic pollution issues with schools (see Case Study 5.9.4)	Various locations across NZ	Mature	Could train educators for broader reach
Zero Waste Education	Provides waste minimisation education units from pre school to year 8, funded by local councils[217]	Various locations across NZ	Mature (since 1993)	Could expand to other regions/ councils
Visy's recycling education	Recyclers in Auckland provide materials to teach students about recycling aligned to the NZ curriculum and can also host school visits[218]	Auckland	Mature	Could host more local school visits but fewer coming through due to recent H&S changes
Keep the Oceans Clean school project	A free educational programme (resource and guided museum visit) linked to NZ curriculum run in conjunction with a sailing race to teach children about ocean plastics	Various locations across NZ	Once off in 2011/12	Future projects could be modelled on this
Wellington Zoo	Working to remove or reduce single-use packaging from use at the Zoo and partner organisations[219]	Wellington	Ongoing	Could share learnings with other zoos

[216] More information available at: http://parakore.maori.nz/
[217] More information available at: https://www.zerowasteeducation.co.nz/
[218] More information available at: https://www.visy.com.au/recycling/education
[219] More information available at: https://wellingtonzoo.com/assets/Resources/Annual-Report-2018.pdf

Table 9 Initiatives related to plastics and sustainability at tertiary institutes

Institute	Example initiative	Maturity	Scalability
University of Otago	University community provided plastic bottle caps which were made into an artwork to educate people about the impact of plastic on marine life[220]	One-off project in 2018	Similar initiatives could be adopted by other universities
University of Auckland	Coordinated a citizen science day with Sustainable Coastlines to collect microplastics data for current research project	One-off event in 2018	Could repeat and support scale of Sustainable Coastlines programme (see Case Study 5.9.4)
Massey University	Joint initiative with Palmerston North City Council on the Plastic Free Palmy project involving citizen science	Ongoing	Similar initiatives could be adopted by other universities
Waikato University	Several waste minimisation initiatives, including the Eco Emporium – a sustainability space, where students can learn new skills, repair things, up-cycle unwanted items, volunteer, or seek advice on waste and sustainability	Ongoing	Similar initiatives could be adopted by other universities

[220] More information available at: https://www.otago.ac.nz/otagobulletin/news/otago693057.html

2.7.2 Case study: Sustainability through connection, learning and action

KA MIHI KI A RANGINUI, KI A PAPATŪĀNUKU
KA MIHI KI TE NGAO O TE WHEIAO

With a kaupapa of creating a healthy, peaceful, more sustainable world, Toimata Foundation supports inter-generational learning and action by running two main programmes in schools and communities:

- **Te Aho Tū Roa:** a programme in Te Reo Māori, working with kōhanga/puna reo, kura, wharekura and communities that embrace Māori culture, language and wisdom. It seeks to strengthen connection between people (including past, current and future generations) and from people to place
- **Enviroschools:** an action-based education programme run through early childhood education centres, primary and secondary schools, where young people explore and connect with their place and then plan, design and implement sustainability projects, becoming catalysts for change in their families and community.

Aspects of Toimata's exemplary approach could guide further educational efforts to support sustainability education and action in schools, including:

Taking a holistic and empowering approach

The number of environmental issues is growing – plastic pollution, deforestation, biodiversity loss, dying rivers, climate change – all symptoms of unsustainable ways of living. This can be a depressing and immobilising situation for young people and adults alike. Focusing on a long list of complex problems to fix can bring feelings of despair and hopelessness. Toimata's educational approach is to explore our interconnection with nature, the roots of sustainability and the abundance of human creativity. Students tackle specific issues that they see in their world from a place of connection with their community and environment, and with confidence in their own identity and abilities. Many programmes tackling specific issues – such as waste reduction, stream care and saving species – work synergistically with Enviroschools and Te Aho Tū Roa, finding fertile ground in schools, kura and communities where sustainability is being woven through the practices, physical places and curriculum.

Learning as a real-life adventure

The Punaha Akoako in Te Aho Tū Roa, and the Enviroschools Action Learning Cycle, are two tools that support learners to explore and take action together in their environment. Toimata want learners to go on an adventure – to discover how things once were; the indigenous stories and ancient wisdoms and ways of living; and the connections that people have to maunga (mountains), awa (rivers) and many other aspects of their place. They want learners to find out how things came to be the way they are now, what they want to change, and that there is no one 'right answer' but a multitude of solutions – some already out there and many more yet to be co-created by them.

The deep and authentic 'education for sustainability' happening in kura and communities reflects real world community-led action. It is people of all ages connecting and working together in nature. It is people growing and cooking healthy kai (food) and caring for each other as they restore the ecosystems that they belong to. It is people laughing together as they build structures and play experiential learning games, developing their brains and bodies, with materials from nature. It

is young people coming alive to their own particular passion, and feeling confident to contribute it to their communities and the world.

Figure 23 Students at Te Noho Taiao o Te Hiku

"IT IS COOL BECAUSE IT IS NOT JUST WESTERN SCIENCE, IT IS MĀORI SCIENCE AND IT IS HANDS-ON… OUR ANCESTORS WERE EXPERTS IN SCIENCE"

Collaboration, networking and sharing

Through Te Aho Tū Roa and Enviroschools, Toimata is supporting over 1300 schools, kura, and early childhood centres – this is around 10% of early childhood centres, 40% of primary and intermediate and 25% of secondary schools. Programmes are also engaging with hundreds of whānau, hāpu, marae and communities, in both English and Māori settings. Toimata Foundation works in partnership with over 100 organisations nationally and regionally. Poutautoko (regional Te Aho Tū Roa people) support learning and action through a highly collaborative approach. Enviroschools Regional Coordinators are generally employed by Regional Councils and they support teams of Enviroschools Facilitators who are in turn supported by a range of agencies, including councils and community organisations. Toimata believe in the power of human networks, bringing people of all ages together to share and learn is an essential part and strength of these programmes.Creating sustainable, resilient communities involves bringing together many different skills, perspectives and resources. The complex environmental, social, cultural and economic challenges facing us today call for a holistic response from a range of different people and organisations working together.

Combining wisdoms, practices and technologies

Toimata believe that through combining wisdoms, practices and technologies, both ancient and new, that truly sustainable ways of living can emerge. The foundation is guided by values of aroha, manaakitanga, whanaungatanga (see Section 1.3.1), Te Reo Māori and restoration; building loving relationships and caring for each other and our world underpins their mahi (work). They work with founding partner Te Mauri Tau, an educational, environmental, and health organisation drawing from the wisdom and knowledge contained within traditional Māori understanding to enhance the wellbeing of the individual, whānau and community.

Educational programmes like Toimata can embed a deep connection to environment and an understanding of sustainable living in the next generation, empowering this group to protect their environment. The strong foundation created by these programmes is reflective of the understanding people need to have to address our plastics issue. There is no simple fix, rather people need to understand the complexities of our current unsustainable lifestyle and recognise the importance of protecting our environment from a range of environmental impacts. This is exactly the kind of holistic thinking we need to conquer our maunga (mountain) of plastic waste.

2.7.3 Actions schools, kura and kindergartens can take

- Engage with the 'Mātauranga whakauka taiao, Environmental education for sustainability. Strategic and action plan 2017 – 2021'.[221]
- Embed learning about, in and for the environment, including in relation to plastics, within cross-curricular learning programmes and as part of the school kaupapa.
- Engage with the local council (see Case Study 2.3.2), local community groups or citizen science projects related to plastics through organisations such as those listed in Tables 7 and 8.
- Encourage projects focused on plastics for science fairs and similar school projects.
- Use games to incentivise students to think about their use or disposal of plastics.
- Access NCEA sustainability standards as part of senior secondary programmes.
- Embed sustainability in the school through whole-of-school programmes (e.g. for recycling and composting).
- Establish a sustainable procurement policy.
- Establish a waste plan and reduction goal for the school.

2.7.4 Actions tertiary institutions can take

- Ensure operational practices reflect responsible use of plastics, including through sustainable procurement of plastics.
- Undertake a plastics audit that covers the curriculum, research and civic arms of the institute to highlight opportunities for improvement.
- Offer courses and teaching units within courses that teach sustainability and issues related to plastics in particular.
- Create greater space in Teacher Education for all student teachers to explore education for sustainability.
- Undertake research on plastics and develop communication channels with end-users to ensure uptake.
- Engage or collaborate in a Massive Open Online Course (MOOC) on marine litter.[222]
- Build the plastics problem into case competitions.
- Act as a 'critic and conscience of society' by ensuring that new research on plastics is made widely available through the media and other public communication channels.

2.7.5 Current barriers to action

Schools, kura and other educational institutions face the same barriers to responsible practice as all institutions, and so therefore may appear to be 'teaching' one thing and 'doing' another. Addressing the following will help to reduce barriers for rethinking plastics efforts in the education sector.

- Resourcing at schools (funds, time in a busy curriculum, teacher expertise, passion and commitment).
- The curriculum and structure of NCEA does not mandate teaching of particular environmental issues, although this has the upside of allowing flexibility and innovation within schools committed to the 'future focus' principle.
- Individual teacher capability and capacity to teach environmental and sustainability education.

[221] Department of Conservation, "Mātauranga Whakauka Taiao, Environmental Education for Sustainability", 2017
[222] https://www.ou.nl/-/unenvironment-mooc-marine-litter

2.7.6 Summary and opportunities for the education sector

The education sector has an important role to play to support cultural transformation in how we use plastics. In order for the sector to be effective in doing this, teachers need to be supported to teach the right topics in a way that empowers students to take action. As a huge government procurement sector, education is an opportune sector to demonstrate sustainable procurement of plastics. Universities also need to demonstrate responsible use of plastics, as well as be supported in research and collaboration related to plastics. Recommendations 3, 5 and 6 address this.

Key considerations for implementing these recommendations:

- There are 'education for sustainability' standards at Levels 2 and 3, but not at Level 1. Nationally, advocates such as the New Zealand Association for Environmental Education have been pushing for these for many years.
- The UNEA UNEP recommended enabling support to integrate green and sustainable chemistry education, innovation and sustainable business models into mainstream curricula in 2019.[223]
- DoC has been driving an education for sustainability strategy and action plan that could be built on for integrating plastics education into schools.[224]
- NOAA's Marine Debris Program in the US supports projects across the country that use outreach and education as a way to prevent marine debris, which could be modelled from locally.[225]

[223] UNEP, "Global Chemicals Outlook Ii: Summary for Policymakers", 2019
[224] Department of Conservation, "Mātauranga Whakauka Taiao, Environmental Education for Sustainability", 2017
[225] For more information see: https://marinedebris.noaa.gov/current-efforts/prevention

2.8 The cumulative power of individual actions

EHARA TAKU TOA I TETOA TAKITAHI ENGARI HE TOA TAKITINI[226]

Governments and big business can take action to achieve substantial, immediate impact on how plastic is used, but individuals and small groups are key to help raise public awareness, create a mandate for policy change, demonstrate new practices and inspire others.

We can think of individuals as being at both ends of the change needed in how we use plastics – individuals are responsible for their own practices and can influence others through social contagion. This grows into larger effects at community and regional levels, and can cause the groundswell that leads to changes implemented by government and industry. Moreover, individuals are voters so they choose who is in power and therefore show governments what action they want. As consumers, individuals can also drive change through their disposable income.

In order for people to want to change a practice there needs to be a value proposition that resonates. When people understand the possible impacts of their choices it may help with motivation to learn a new practice. At the same time, people are limited to making choices within the system that they are part of. If systems are not in place, it makes it difficult or impossible for people to do the right thing.

People's individual acts are noticed by others. As copiers by nature, people may then adopt the behaviour as their own. This can help create 'social contagion' in which a particular practice grows.[227] The rapid adjustment of New Zealanders to taking their own bags to the supermarket, rather than rely on being provided with them at the store, is an excellent example. Data from the General Social Survey collated by Statistics NZ captured how New Zealander's behaviours changed in preparation for the bag ban. It showed before the ban took place more people were using reusable bags, with most significant increase in young people. Use was almost universal before the ban set in, with 96% of people saying they or someone in their household used reusable bags.[228] This was helped by many supermarkets encouraging such practices, and hence the structural environment supported individual motivation to change.

Once practices become habitual, they become part of the individual's identity and the person concerned will then carry the practice into other settings. This may include agitating for the change necessary to facilitate the practice.[229] There may also be spill over effects in which adopting one environmentally responsible practice leads to other related practices (see Case Study 2.8.2).[230]

Individuals are always limited by the social context and the opportunities available to them. Most people, most of the time, will do what the situation demands of them. This is why a sustainable change in our relationship with plastics will require both encouraging change agents to demonstrate alternatives, and holding more responsible practices in place through changes to policy and law.[231]

People also learn from 'behavioural traces' which are physical signs of the normal and expected behaviour in a particular environment. Waste management systems and the labelling of products can help create behavioural traces that

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[226] My strength is not that of an individual but that of the collective

[227] Christakis et al., "Social Contagion Theory: Examining Dynamic Social Networks and Human Behavior," *Stat Med* 32, no. 4 (2013); Harré, *Psychology for a Better World: Working with People to Save the Planet* (Auckland: Auckland University Press, 2018); Long et al., "Understanding Change in Recycling and Littering Behavior across a School Social Network," *Am J Community Psychol* 53, no. 3-4 (2014)

[228] Statistics New Zealand, "In the Bag – Kiwis React to Banning Single-Use Plastic Bags", press release, 29 July 2019, http://www.scoop.co.nz/stories/BU1907/S00705/in-the-bag-kiwis-react-to-banning-single-use-plastic-bags.htm

[229] McAdam, *Freedom Summer* (New York: Oxford University Press, 1988)

[230] Elf et al., "Facilitating Positive Spillover Effects: New Insights from a Mixed-Methods Approach Exploring Factors Enabling People to Live More Sustainable Lifestyles," *Front Psychol* 9 (2018)

[231] Harré, *Psychology for a Better World: Working with People to Save the Planet*; Harré, *Psychology for a Better World: Working with People to Save the Planet*.

encourage people to 'do the right thing' (see Section 3.6.2 on labelling).[232] In particular, bins that separate rubbish act as behavioural traces that enable positive action from individuals.

Individuals can also notice problems with the system around them and raise concern. Recently a high-school student raised the issue of exams being wrapped in plastic and alerted a Member of Parliament to take this to parliament.[233] This is an example of a person noticing something wrong and taking action. Understanding the forces of social contagion will be critical in inspiring New Zealanders to reduce their plastic consumption.

2.8.1 Local initiatives and ongoing efforts

There are several existing initiatives that can support individuals to rethink their use of plastics, as outlined in Table 10, that could be taken up by others and built on.

Table 10 Examples of local initiatives that help individuals change their relationship with plastic

Initiative	Details	Location	Maturity	Scalability
Plastic Free July[234]	A challenge to refuse single-use plastic for the month of July	Global and being implemented in various locations in NZ	Mature	Easily scaled and applied by individuals through to larger organisations
Connecting Good[235]	Accreditation scheme for businesses demonstrating sustainable practices that gives consumers a vote to influence business decisions	National	Mature	Currently used by 13,000 Kiwis
ReCircler[236]	Interactive consumer-facing platform that companies can use to advertise take back schemes to divert waste from landfill to be recycled	Christchurch	In development (awaiting funding)	Pitched for Christchurch but if funded should be considered for effectiveness and scalability nationally

[232] Goldstein et al., "Using Social Norms as a Lever of Social Influence," *Science of Social Influence: Advances and Future Progress* (2007)
[233] Honey, "Why I'm Taking on My School Examiners over Their Plastic Habit", *The Spinoff*, 23 August 2019
[234] More information available at: https://www.plasticfreejuly.org/
[235] More information available at:https://nz.cogo.co/
[236] See the pitch presentation at: https://www.youtube.com/watch?v=t1R89Q_VVJ0andfeature=youtu.be

2.8.2 Case study: Saying no to single-use coffee cups

A spill-over effect of the recent single-use plastic shopping bag ban is that many people who have now adopted the practice of taking reusable bags to shops are making other efforts to avoid single-use products where possible. This is particularly evident for reusable coffee cups, with numerous initiatives underway to support people to choose a more sustainable alternative.

Figure 24 Single-use coffee cups headed for landfill. Photo credit againagain.co

It is estimated that New Zealanders go through 295 million single-use takeaway coffee cups each year.[237] Purchasing coffee is certainly a habitual practice – and there is great opportunity to support individuals to make that practice more sustainable.

Most cafes now accept reusable cups. People can choose to purchase a reusable cup and take that with them when they buy a coffee. Common Ground Coffee in Dunedin managed to grow the percentage of takeaway coffees that were in reusable cups from 8% to over 60% in just 14 months by having staff talk to customers about the issue of single-use cups and champion reusable cups. The cafe noted that there was a tipping point when around one in every three customers had a reusable cup – the social contagion effect caught on and people were self-conscious if they were not being part of the sustainable movement.[238]

THE CAFE NOTED THAT THERE WAS A TIPPING POINT WHEN AROUND ONE IN EVERY THREE CUSTOMERS HAD A REUSABLE CUP – THE SOCIAL CONTAGION EFFECT CAUGHT ON AND PEOPLE WERE SELF-CONSCIOUS IF THEY WERE NOT BEING PART OF THE SUSTAINABLE MOVEMENT

There will be times when people forget their reusable coffee cups and then their choice is limited to what is available to them. That is where initiatives for renting reusable coffee cups play a significant role. Again Again,[239] Globelet,[240] the Taranaki cup library[241] and Ideal Cup[242] are all based on a similar model of paying a small deposit for a reusable cup when buying a coffee, which is redeemable when you return the cup to any cafe participating in that scheme. These initiatives encourage and support people to adopt a practice of reuse while preventing single-use items ending up in the landfill. To ensure this kind of change spreads throughout the whole community, regulation may be necessary. This could be tested before it is implemented to see the outcome and how effective it is in supporting changing practice through bylaws in certain regions.

[237] More information available at: https://www.recycling.kiwi.nz/campaigns/compostable-coffee-cups/
[238] Huffadine, "Use Your Own Cup: Tackling Single-Use Culture One Cup at a Time", *Radio New Zealand*, 18 February 2019
[239] More information available at: https://www.againagain.co/
[240] More information available at: https://www.globelet.com/
[241] New Plymouth District Council, "Coffee Beans Add Zing to Zero Waste Journey", press release, 22 March 2019, http://www.scoop.co.nz/stories/AK1903/S00659/coffee-beans-add-zing-to-zero-waste-journey.htm
[242] More information available at: https://www.idealcup.co.nz/cupcycling/

2.8.3 Case study: Reducing cigarette butt litter

Cigarette butts account for 78% of all items littered in Aotearoa New Zealand and these are the most commonly found item in beach litter clean ups.[243] A significant proportion of people who litter cigarette butts in Aotearoa New Zealand don't recognise them as plastic or consider it littering.[244] We're not alone facing this issue. It is estimated that of the 5.5 trillion cigarettes produced worldwide, 4.5 trillion cigarette butts are littered.[245] This makes cigarette butts the most littered item on Earth. The evidence suggests that we need educational efforts and new systems to support smokers to change the practice of discarding cigarette butts to stop this form of pollution at source.[246] There is a need to change perceptions about cigarette butts as harmless litter. This will be complex as litter forms part of the smoking ritual itself.

THERE IS A NEED TO CHANGE PERCEPTIONS ABOUT CIGARETTE BUTTS AS HARMLESS LITTER

After finding similar results in their local litter studies, the NSW Environment Protection Authority (EPA) led a collaborative behaviour change trial in partnership with 16 local councils to understand what strategies are effective in reducing cigarette butt littering behaviour.[247] Four key strategies were tested across 40 smoking sites:

- **Pathways:** Creating the best environment for smokers to correctly dispose of their butts by placing signs on butt bins and stencils on the ground to create pathways to the location of butt bins.
- **Pride and Ownership:** Encouraging smokers to develop a sense of pride in, and ownership of, the area as a comfortable and welcoming place for smokers, thereby creating a commitment to bin their butts.
- **Positive Social Norming:** Encouraging smokers to believe it is expected that smokers using the area will dispose of their cigarette butts in the bins provided; calling on smokers to act responsibly, reinforcing positive feelings they get from disposing correctly and meeting a target of zero butt litter for the location.
- **Enforcement:** Raising the risk attached to littering by drawing smokers' attention to fines; boosting patrols with rangers (enforcement officers) speaking to smokers in the locations to increase the rangers' visibility; and providing an incentive not to litter based on avoiding a penalty, with the option to move on to 'hard enforcement' that involves issuing infringement notices to smokers who litter their butts.

Each strategy led to an increase in binning rates. The best results were consistently found with 'pride and ownership' strategies, though participants considered the pathways approach to be the easiest and most cost-effective intervention.

Efforts to reduce littering of cigarette butts into our environment could look to the learnings from the NSW EPA behaviour change study and follow the roll-out of the full programme in 2020.

Supporting the change in behaviour for smokers who litter cigarette butts could be done in conjunction with policy measures that further reduce the likelihood of cigarette butts entering our environment, such as product stewardship frameworks, deposit schemes[248] and recycling programs.[249]

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[243] Data from Keep New Zealand Beautiful's national litter audit and Sustainable Coastline's beach clean-up dataset shine a spotlight on Aotearoa New Zealand's problem with littered cigarette butts. https://litterintelligence.org/ and https://www.knzb.org.nz/wp-content/uploads/2019/09/KNZB-2019-National-Litter-Audit-Report.pdf

[244] Of the people who were observed littering and were subsequently interviewed, 53% admitted to having littered. Forty-two per cent of the people who had been observed littering claimed to have never littered – all of these people had littered cigarette butts Keep New Zealand Beautiful, "National Litter Behaviour Research", 2018

[245] Torkashvand et al., "A Systematic Review on Cigarette Butt Management as a Hazardous Waste and Prevalent Litter: Control and Recycling," *Environmental Science and Pollution Research* 26, no. 12 (2019)

[246] Cigarette filters are made of a plastic called cellulose acetate. When tossed into the environment, they dump not only that plastic, but also the nicotine, heavy metals, and many other chemicals they've absorbed into the surrounding environment. See: https://www.nationalgeographic.com/environment/2019/08/cigarettes-story-of-plastic/

[247] More information available at: https://www.epa.nsw.gov.au/your-environment/litter-and-illegal-dumping/epa-work-prevent-litter/reducing-cigarette-butt-litter

[248] Scott Metcalfe, "A Kick in the Butt: Time to Address Tobacco Waste in New Zealand," 130, no. 1456 (2017)

[249] Terracycle have a cigarette waste recycling programme currently available in 598 locations https://www.terracycle.com/en-US/brigades/cigarette-waste-recycling/brigade_faqs

2.8.4 Actions that individuals can take

People are inspired by the action of others. Therefore, each person can make changes that may not only reduce their use of plastic or its impact on the environment, but also inspire others around them to make similar changes. Individual actions that will contribute to the transformative change in our relationship with plastics include:

- Supporting businesses that use plastic alternatives.
- Doing a bin audit to see what waste could be avoided, recycled or composted (there are instructions of how to do this on the Plastic Free July website).[250]
- Carrying reusable items with you when using them regularly. This might include cups, drink bottles, bags for fruit and vegetables, cutlery for takeaway meals.
- Choosing alternatives to plastic when available and affordable.
- Refusing unnecessary plastics (e.g. straws, lids on coffee cups, plastic wrap).
- Choosing products made from recycled and recyclable content.
- Repairing broken products when possible or take to e-waste or resource recovery station.
- Disposing of products as directed (recycling or landfill) based on the product's labelling and local council instructions.
- Talking about responsible plastic use and disposal with others.
- Listening to the suggestions of others, especially children, who have up-to-date knowledge about plastics or who are concerned about their impact.
- Researching and advocating for plastic alternatives in your workplace, school or community organisation.
- Joining a local group that is campaigning reform to plastic related legislation or policy.
- Looking for opportunities to make submissions on local or national policy and legislation in this area.
- Avoiding fast fashion by buying fewer clothes and not disposing of clothes that are not worn out.

Examples of brands using innovative approaches to support people to change their practices follow in Chapter 3.

PRIME MINISTER JACINDA ARDERN ANNOUNCING THE PLASTIC SHOPPING BAG BAN

"I also underestimated the strength of feeling amongst everyday New Zealanders around this issue. One of the groups of people that have helped me realise how much people care about plastics in the environment were children.

The biggest issue I get letters on from the public are about plastics and it comes from children. I literally get hundreds and hundreds.

We in government have a role to play in the way we manage these kinds of issues and the way we respond to the public when they call upon us to address what might seem like a small issue."[251]

Figure 25 Prime Minister Jacinda Ardern at the announcement of the bag ban. Photo credit: Sustainable Coastlines

[250] More information available at: https://www.plasticfreejuly.org/get-involved/what-you-can-do/bin-audit/
[251] "Government Pledges Mandatory Phase-out of Plastic Bags", 12 August 2018

2.8.5 Current barriers to action

A broad barrier to people changing their practice is that often doing things a different way isn't feasible, because the right systems are not in place to support that change. Other barriers include:

- **Lack of easily accessible consumer-friendly information to support better practice** (e.g. what happens to recycled products, coloured PET doesn't always get recycled).
- **Misconceptions:** There are common misconceptions in the public about what can be recycled and what the recycling symbols mean (see Section 3.6.2). This highlights the need for both standardisation of labelling and public education.
- **Lack of a better alternative:** In many cases plastic is the cheapest, lightest, strongest and most convenient and one or more of these factors would need to be sacrificed for an alternative. Plastic can also contribute to enhancing food safety, extending product stability and shelf life, and reducing food waste.
- **The entanglement of plastic use with other valued practices or principles.** For example, disposable plastic plates, cups and cutlery accompany eating out with friends from many outlets; cheap plastic toys allow people to give children affordable gifts; single-use plastic is considered 'hygienic' in many circumstances. Organisations such as schools and sports clubs can help to change the culture of plastic use and normalise it to be spread further.
- **Ease and accessibility of disposal options:** Keep New Zealand Beautiful's Litter Behaviour Study identified that people who littered most commonly said they did so because there were no bins around.[252] There is also evidence that convenience is one of the strongest predictors of householders' recycling behaviour.[253] This highlights that making good practice easy and convenient for people is a key way to reduce litter pollution and increase rates of recycling.
- **The sense that plastic is not a 'real' problem or the government would have acted on it.** If a society's leaders are not visibly taking action, then it may be very hard for people to take an issue seriously. At present, responsible use of plastic, may be seen as a 'virtue' but it is not morally required.[254,255] This requires government-led action to demonstrate responsible use of plastic and also regulatory action to show that this is significant issue that needs addressing.

2.8.6 Summary and opportunities for individuals

Most people want to do the right thing, but they need to know what the right thing is to do and have the systems in place to make it easy to do it. Ultimately, we need a system that allows individuals to change their relationship with plastics – whether that's through using less plastic overall or ensuring that the plastic materials they use remain in circulation. The key components that will help individuals change their practices are addressed in recommendations 3 and 4.

Key considerations for implementing these recommendations:

- A public education campaign could use simple, consistent messaging linked in with new, clear systems.
- The WasteMINZ bin audit could inform messaging for a public education campaign.
- Ambassadors could be an effective way to get messages through to the public. It was recently announced that the new All Blacks training kit will be made from upcycled marine plastic waste – and that some members of the team were driven to become ambassadors after an educational session on marine plastic waste.[256]

[252] https://www.litter.org.nz/assets/Uploads/Behaviour-Study/6414f5b4d5/KNZB-Litter-behaviour-report-DRAFT-0.3-Released-3.4.18.pdf
[253] Miafodzyeva et al., "Recycling Behaviour among Householders: Synthesizing Determinants Via a Meta-Analysis," *Waste and Biomass Valorization* 4, no. 2 (2013)
[254] Hauser, *Moral Minds: The Nature of Right and Wrong* (New York: HarperCollins 2006)
[255] Harré, *Psychology for a Better World: Working with People to Save the Planet*.
[256] "All Blacks' New Training Kit to Be Made from Recycled Plastic", 1 April 2019

2.9 Part of a global community

Aotearoa New Zealand is not the only country that needs to take transformative action and change our relationship with plastics – the issues related to the scale and disposability of plastic are global. Many other countries or jurisdictions are also taking action, and our country needs to align efforts with those that are leading the charge through agreements and initiatives (as discussed in Section 1.2.1). Aotearoa New Zealand does not have to face these challenges in isolation, but instead should focus on connecting with international groups and sharing best practice, and bringing great ideas from overseas home and tweaking these to fit our local context. We can also help our neighbours in the Pacific to deal with the issues of plastic waste.

There are several opportunities to connect with the international community on plastics, such as:

- Embedding more sustainable use and management of plastics in trade agreements and establishing international product stewardship principles
- Aligning data collection efforts to international guidelines to support aggregation of data
- Fostering international research collaborations, including connecting to research by indigenous communities in other countries
- Connecting citizen science efforts to international citizen science projects
- Signing international pacts or treaties related to plastic use and waste
- Aligning regulatory practices with external trading partners
- Connecting to international NGO or government-led working groups (e.g. WRAP) to share knowledge
- Sharing knowledge and building scale for clean-up efforts (particularly with Pacific Island nations)
- Modelling best practice, including managing our own waste and not exporting large volumes of plastic.

2.9.1 Summary and opportunities for global connections

Connecting our efforts to transition to a more circular economy for plastics and remediate plastic pollution with the international community is a critical part of rethinking plastics. This is addressed in a number of recommendations within recommendations 2, 3 and 6.

Key considerations for implementing these recommendations:

- Opportunities to incorporate plastics into trade agreements could be considered, e.g. extending product stewardship schemes across national borders, as suggested at the recent CPTPP forum on marine plastics.
- As the host of APEC 2021, Aotearoa New Zealand could highlight circular economy principles for plastics as an area for cooperation among this influential group of 21 economies.

3. Ideas for a more sustainable future – embracing innovation

"THE STORY OF OUR SPECIES IS ONE OF OVERCOMING EXISTENTIAL RISK THROUGH NEW FORMS OF COOPERATION AND INNOVATION"

DAVID GRINSPOON IN *EARTH IN HUMAN HANDS: SHAPING OUR PLANET'S FUTURE*, GRAND CENTRAL PUBLISHING, 2016

In this chapter, we introduce innovative ideas that can help us shift to a more sustainable use of plastics. These are framed as actions that align to the 6rs – rethink, refuse, reduce, reuse, recycle and replace – as well as options for disposal as we move towards zero plastic waste.

3.1 The pathway to our future vision

The development of plastics and all plastic products is born from innovative thinking and design. Our urgent need to rethink plastics provides an environment for more boundary-pushing ideas. New ideas and innovative thinking are needed across the whole system of how we use and dispose of plastic. Many of these ideas exist already and need to be accepted, scaled to context and location and implemented as part of complex changing social systems.

The challenge to use plastic sustainably is ripe with opportunities for innovation. But the nature of innovation is not linear. Many breakthroughs and game-changing ideas come from left field and arise in response to a new need. To achieve the goals of rethinking plastics, we can construct a system that enables an innovative environment – one that doesn't prescribe the solutions people come up with, but instead is receptive to new ideas. The research and innovation system can then nurture game-changing ideas and support scale-up of those that are proving to be successful.

Figure 26 The 6Rs guide our ideas and innovations for rethinking plastics

Plastics are so ubiquitous in our lives and the issues posed by them are now so large that a single innovation, or even a single type of innovation, will not solve the challenge. There is no silver bullet. New materials and new machines, new recycling techniques, new uses for recycled materials, new business models, and perhaps most importantly, citizens who are ready to form a new relationship with plastics are all needed (as detailed in Chapter 2).

PLASTICS ARE SO UBIQUITOUS IN OUR LIVES AND THE ISSUES POSED BY THEM ARE NOW SO LARGE THAT A SINGLE INNOVATION, OR EVEN A SINGLE TYPE OF INNOVATION, WILL NOT SOLVE THE CHALLENGE

The development and adoption of new technologies can be a long, slow business. If we are to meet our aspirations to reduce our use of plastics and keep the plastics we use in circulation, we cannot wait for technological fixes to be developed – the key will be maximising the technologies we have already and encouraging fast adoption of new ways of thinking and new behaviours, as individuals, communities, businesses and government. It will also be important to ensure that pathways to later ideas that might provide better answers than the ones we can see today are not inhibited by rushing to quick solutions. For example, it would be disadvantageous to invest in recycling infrastructure for a particular type of plastic if a more sustainable alternative that is not compatible with this technology is just around the corner.

Innovation that supports the system-wide transformative change needed in how we use and dispose of plastics will be ongoing. In this chapter, we present a snapshot of ideas and innovations based on the principles of the 6Rs that can be adopted now or in the future. Supporting continued innovative thinking, sharing of ideas and supporting scale-up of the most successful concepts in this space will be key to making these examples of best practice, standard practice.

3.2 Rethink

Many of the issues raised by plastics are not caused by the properties of the plastics themselves but by the way we design, use and dispose of them. As a contrast, gold is as persistent in the environment as plastics but its initial cost and recycled value are strong incentives for it not to accumulate in landfill. If packaging were made of gold, we would not have a recycling problem![257] Plastic on the other hand is seen as disposable and part of our 'throw away' culture. Plastic products and packaging materials tend to be designed around cost, convenience and appearance, without consideration of end-of-life options. Even when issues such as biodegradability, recyclability and other options are considered, decisions are often made for functional and marketing reasons without a solid evidence-base for their overall impact on the environment (see discussion around methods to support this in Section 4.3). Rethinking and redesigning plastics requires a whole-of-life accounting approach to better account for the environmental costs of plastic and not just the cost of putting a product on the market. Product stewardship schemes are one way to begin this.[258]

Figure 27 An example of a collection bin for compostable plastics to take them to an industrial compostable facility at Wellington Airport

Factoring in the whole-of-life costs of a product will likely lead to a more sustainable result. Products can be designed in a way that extends their use, improves their recyclability in the local context, or reduces the chance of contributing to environmental leakage. As discussed in Chapter 2, manufacturers currently seeking sustainable solutions struggle to navigate complex issues with no clear guidance from government. How aligned new design is to the future plastics economy of Aotearoa New Zealand will be limited by the support given to businesses by government and the degree to which good practice can be shared and scaled. Ideas that could form part of a system-wide rethink in how we use plastic are listed in Table 11.

[257] Szaky, *The Future of Packaging: From Linear to Circular* (United States: Berrett-Koehler Publishers, 2019)
[258] More information available at: https://www.mfe.govt.nz/waste/we-all-have-role-play/businesses-taking-responsibility-for-their-products

Table 11 Ideas and innovations that can help us rethink plastics in Aotearoa New Zealand

Idea	Who	Examples/ early adopters	Strengths	Limitations for implementation	Possible solutions
Guidelines and a code of practice for industry	Industry/ Government partnership, to be followed by business	WRAP[259] APCO PREP tool[260] Packaging NZ's code of practice[261] Danish circular plastic packaging manual[262] UK circular economy standards[263]	Can support a reduction in use of problematic plastic or packaging designs Businesses that have been waiting to see government direction before investing in change can do so Helps businesses consider life cycle of material (e.g. only use compostable packaging if collection systems, e.g. Figure 27)	Exported packaging needs to meet specific country's requirements Immature infrastructure so difficult to deal with all plastics that businesses will be directed to use onshore Many products used and disposed onshore are imported	Develop clear guidelines for polymer, additive and colour use, and when to use single-use, compostable and reusable packaging Signal the direction of infrastructure development and timelines on any polymer bans to industry
Sustainable product design so all resources stay in the economy (see Table 12 for designing out plastic and Section 3.7 for sustainable materials)	Brand owners/ manufacturers	EMF published a series of case studies demonstrating circular design[264]	Designing for longevity, remanufacture, or material recovery can reduce waste Use of LCA supports evidence-informed product design and factors in full life cycle environmental costs (see Section 4.3)	Lack of incentive to change current practice Limited funding aimed at innovation to rethink plastics Cost of LCA studies prohibitive for some businesses and most are commercially sensitive	Expand waste levy to disincentivise waste[265] Mandate product stewardship Support access to LCA info for businesses Funding and environment that enables innovation
New business models based on leasing vs ownership and the 'sharing' economy	Industry	Again Again coffee cups[266]	Reduces waste by increasing the reuse of products Supports a change in practice around	High upfront cost for inventory for such business models	Funding and environment that enables innovation

[259] More information available at: http://www.wrap.org.uk/polymerchoiceguidance
[260] More information available at: https://prep.org.au/main/content/home
[261] Packaging New Zealand's Code of Practice is available to members at: http://www.packaging.org.nz/page/15/code-of-practice
[262] Forum for Circular Plastic Packaging under the Danish Plastics Federation, "Reuse and Recycling of Plastic Packaging for Private Use", 2018
[263] More information available at: https://www.bsigroup.com/en-GB/standards/benefits-of-using-standards/becoming-more-sustainable-with-standards/BS8001-Circular-Economy/
[264] More information available at: https://www.ellenmacarthurfoundation.org/circular-economy/concept/building-blocks
[265] Eunomia Research & Consulting Ltd, "A Wasted Opportunity - Using the Waste Disposal Levy to Create Economic and Environmental Advantage in Aotearoa New Zealand", 2017
[266] A reusable cup lending system for takeaway coffee. More information available at: https://www.againagain.co/

Idea	Who	Examples/ early adopters	Strengths	Limitations for implementation	Possible solutions
			the need for ownership		
Circular system redesign through collaboration, use of AI and/or big data and blockchain	Multiple businesses/ industries	XLabs: a circular economy lab for businesses in Auckland[267] Coreo circular experiment[268] Google Impact Challenge supporting initiative such as Gringgo[269] SAP's Plastics Cloud[270] Circularise[271]	More likely to find resource or use a waste product if more businesses involved Big data can support industrial symbiotic processing (wastes or by-products of one industry or process becoming raw materials for another) where it is difficult to determine manually[272]	Fragmentation – particularly with small businesses who struggle to reach economies of scale Challenges of complex global supply chains, cross-border trade of products, e-commerce and recycling[273] Access to AI, blockchain, and available data	Run a pilot project for a shopping strip or town[274] Technological developments enabling effective small scale distributed approaches Connect businesses to repurpose waste streams as a resource or share logistics – could model off Industrial Symbiosis MBIE programme run by Scion for biorefineries[275] R&D to support digital tools guiding circular transition

[267] A lab that will help businesses unlock innovation and address key challenges and leverage opportunities following circular economy principles, to be run in March 2020. See: https://www.xlabs.nz/

[268] Coreo (an Australian company) is working with Brisbane Airport Corporation to eliminate coffee cups including their plastic lids from the domestic terminal, which is almost 5 million cups per year. To achieve this they have and are continuing to do extensive stakeholder engagement and material flow and systems analysis. The new system will be "coffee cup as a service" and Coreo are partnering with Globelet to design and deliver this world-first project. This project will also see all of the front end infrastructure (public facing bins) and back end infrastructure redesigned to capture clean material streams. See: https://www.coreo.com.au/

[269] More information on Google's Impact Challenge is available at: https://ai.google/social-good/impact-challenge/ and more information about an example initiative related to plastics is available at: https://gringgo.co/

[270] SAP news, "Sap Launches 'Plastics Cloud' to Help Reduce Single-Use Plastic Waste", press release, 17 September 2018, https://news.sap.com/uk/2018/09/sap-launches-plastics-cloud-to-help-reduce-single-use-plastic-waste/

[271] An open protocol for a decentralised network that brings transparency to global supply chains and empowers businesses to take steps towards a circular economy. More information available at: https://www.circularise.com/

[272] Song et al., "Industrial Symbiosis: Exploring Big-Data Approach for Waste Stream Discovery," *24th Cirp Conference on Life Cycle Engineering* 61 (2017)

[273] UNEP, "Global Chemicals Outlook Ii: From Legacies to Innovative Solutions: Implementing the 2030 Agenda for Sustainable Development – Synthesis Report", 2019

[274] Model for Coreo's circular experiment. See https://www.coreo.com.au/experiment

[275] More information available at: https://www.scionresearch.com/__data/assets/pdf_file/0019/60607/Industrial_symbiosis.pdf

3.3 Refuse

One of the simplest ways to lower the amount of plastic in the environment is to not use it in the first place. Refusing certain types of plastic would also help to support infrastructure by funnelling economies of scale, which will benefit collection, sorting, processing, reuse and recycling options. In Chapter 2, we discussed how individuals can change their habits to refuse unnecessary use of plastics and outlined some actions businesses can take to support transformative change in how we use plastic, including some local examples. In Table 12 we highlight innovative approaches that can reduce the overall amount of plastic entering the market.

Figure 28 Ethique is an Aotearoa New Zealand company that produces concentrated, plastic-free cosmetic products

Table 12 Ideas and innovations that support refusing plastics in Aotearoa New Zealand

Idea	Who	Examples/ early adopters	Strengths	Limitations for implementation	Possible solutions
Ban certain single-use plastic products and types of plastic for certain applications	Government	Banned single-use plastic shopping bags (see Case Study 4.4.1) Bans as of 2018 detailed in UN report[276] The EU[277] and Canada[278] banning single-use products and types of plastic for food and beverage packaging by 2021 EMF recommend limiting PVC (#3), EPS (#6) + labels for packaging[279]	Removes the plastics that cause the most harm, supporting more sustainable plastic use Will drive innovation to replace these materials (see Section 3.7)	Slow and still requires other system changes Need to give business plenty of time to redevelop packaging where necessary	Implement bans alongside other changes, e.g. product stewardship with incentives that drive the use of preferred plastics, a targeted tax on problematic materials and/or subsidy for approved materials
Concentrated and compressed products that eliminate plastic packaging	Brands	Ethique beauty bars (see Figure 28)[280] Dishwashing tablets[281] Toothpaste tablets[282] Edible sachets[283] TrioCup[284]	In some cases, removes plastic use altogether May reduce transport emissions	Can take a significant investment to develop Need to compete against well-established products with a foothold in market Need to ensure product isn't more environmentally problematic than what it is replacing	Support for R&D for innovations that reduce or remove plastics Brands can connect with retailers who want to provide customers with sustainable options Perform LCA studies to compare new product or packaging against current alternative (see Section 4.3)

[276]UNEP, "Single-Use Plastics: A Roadmap for Sustainability", 2018
[277] European Commission, "European Parliament Votes for Single-Use Plastics Ban", press release, 18 January 2019, https://ec.europa.eu/environment/efe/news/european-parliament-votes-single-use-plastics-ban-2019-01-18_en
[278]Government of Canada, "Canada to Ban Harmful Single-Use Plastics and Hold Companies Responsible for Plastic Waste", press release, 10 June 2019, https://pm.gc.ca/en/news/news-releases/2019/06/10/canada-ban-harmful-single-use-plastics-and-hold-companies-responsible
[279] Ellen MacArthur Foundation, "The New Plastics Economy Global Commitment ", 2017
[280] More information available at: https://ethiquebeauty.com/
[281] More information available at: https://ecotab.co.nz/
[282] More information available at: https://ecoeasy.co.nz/products/toothpaste-tabs
[283] More information available at: https://www.newplasticseconomy.org/innovation-prize/winners/delta
[284] More information available at: https://www.newplasticseconomy.org/innovation-prize/winners/triocup

3.4 Reduce

By 2050, plastics manufacturing and processing may account for as much as 20% of petroleum consumed globally and 15% of the annual carbon emissions budget.[285] However, it is important to remember that while plastic is itself a contributor to carbon emissions, it also helps to reduce emissions by offering a lightweight alternative to materials such as metal and glass (discussed further in Chapter 4). In order to retain the benefits of plastic and balance these against a need to reduce fossil-fuel consumption, innovation is required to reduce the amount of plastic we use and shift to using bio-based and/or recycled plastic where possible (see Section 3.7). Manufacturers and polymer scientists can work to reduce the amount of plastic used in certain applications. In Table 13 we highlight ideas that may help to reduce the amount of plastic used.

Table 13 Ideas and innovations to reduce the amount of plastic used in Aotearoa New Zealand

Idea	Who	Examples/ early adopters	Strengths	Limitations for implementation	Possible solutions
Light-weighting materials	Plastics industry	DuPont developed thermoplastics to replace metal and plastic car components[286] Nestlé reduced weight of water bottles by 22%[287]	Product fulfils same purpose Reduces emissions	Can reduce the effectiveness of mechanical recycling Some sorters at MRFs cannot detect plastics if too light Can take a significant investment even for small reduction for brand Manufacturers may not have infrastructure needed	Support innovation or R&D across businesses that benefits all Collaboration between businesses and researchers Equip NZ manufacturing industry with necessary processing equipment Equip recycling industry with infrastructure adapt to lighter bottles In silico testing
Changing product to reduce required plastic packaging	Brands	Unilever made a laundry liquid 6x more concentrated and reduced plastic volume by 75%[288]	Material cost savings Reduced emissions from transport	Cost of R&D to change product may prevent brands doing this May depend on a willingness of consumers to change a practice	Regulate to ensure whole-of-life costing via product stewardship of products to drive business to reduce use of packaging

[285] World Economic Forum, "The New Plastics Economy: Rethinking the Future of Plastics", 2016
[286] More information available at: https://www.dupont.com/products-and-services/plastics-polymers-resins/thermoplastics/uses-and-applications/automotive-engine-covers.html
[287] More information available at: https://www.nestle.com/ask-nestle/environment/answers/tackling-packaging-waste-plastic-bottles
[288] More information available at: https://www.unilever.com/sustainable-living/reducing-environmental-impact/waste-and-packaging/rethinking-plastic-packaging/

3.5 Reuse

There has been a significant amount of innovation for reuse systems in recent years. In Section 2.5, we shared some local examples of businesses facilitating reuse or establishing new business models based on reuse systems. The Ellen MacArthur Foundation (EMF) published a detailed report on reusable packaging, which includes examples of innovative reuse systems.[289] In the report, EMF describe four reuse system models for business to consumer packaging: the user refills at home, refills on the go, or returns the packaging from home or on the go. Different systems are needed for non-packaging industries and business to business (B2B) packaging or products. In Table 14, we highlight ideas to support reuse of plastics.

Table 14 Ideas and innovations to support reuse of plastics in Aotearoa New Zealand

Idea	Who	Examples/ early adopters	Strengths	Limitations for implementation	Possible solutions
Reusable systems to replace single-use products or packaging	Businesses	EMF shares 69 examples, including Globelet – a local company (see Case Study 5.6.3)[290]	Cuts costs Builds brand loyalty Improves user experience Gathers intelligence Optimises operations Adaptable to individual needs	Difficulty reaching economies of scale Competing against convenience of buying new single-use product	Adapt global ideas to local system Establish reward schemes to drive uptake Education for businesses and retailers
Logistics innovation in supply chains for reusable secondary and tertiary packaging	Industry	CHEP provides reusable options to reduce single-use plastics in logistics (see Case Study 3.5.1) Foodcap[291]	Benefits all parties in the supply chain	Small population and large geographical distances present particular challenges	Ensure solutions are designed for NZ
Product libraries	Community groups/ councils	Toy libraries across NZ[292] Tool libraries	Changes ideas about need for ownership Reduces waste by keeping product in circulation	Resource to get up and running Profitability or reliance on volunteers	Partner with businesses or organisations to give second-life to old equipment

[289] Ellen MacArthur Foundation, "Reuse - Rethinking Packaging", 2019
[290] Ellen MacArthur Foundation, "Reuse - Rethinking Packaging", 2019
[291] More information available at: https://foodcap.com/
[292] More information available at: https://www.toylibrary.co.nz/

Idea	Who	Examples/ early adopters	Strengths	Limitations for implementation	Possible solutions
Logistics innovation to keep products in circulation (e.g. toys)	Business	Lego is piloting a free return system for unwanted bricks to be given to children in need[293]	Easy for people to return Reduces waste to landfill	Distance from manufacturers or brands if multinational may make logistics difficult	Connect systems with Australia Develop local solutions for unwanted toys – e.g. give to toy libraries
Sterilisation of single-use products for reuse	Medical industry	Medsalv reprocess single-use medical devices[294]	Cost savings Reduction of waste to landfill Tracked process for safety and quality assurance	Most hospital's sterile service departments do not have access to equipment for cleaning intended single-use products	Support scale-up of organisations like MedSalv who have this equipment
Refill stations and services	Businesses/ community groups/ Government	RefillNZ (water)[295] Ecostore refill stations[296]	Provides system for people to reuse bottles, reducing overall plastic use May prevent litter	Resourcing required for public stations for water Competing against convenience of buying new single-use product	Prioritise resource here to reduce spend required to clean up the environment later Incorporate cost of packaging into product cost to balance against convenience
Repair and reuse businesses or organisations	Businesses, community groups, local councils	Op-shops Secondhand shops Community reuse centres Repair cafes	Can give a wide range of products a second life Can provide funds to community groups	Competing against new products May rely on volunteers	Partnerships between community groups and councils Embed within other organisations

[293] Verdon, "Lego's Latest Green Initiative Wants to Put Old Bricks to New Use", *Forbes*, 8 October 2019
[294] More information on MedSalv's reuse system is available at: https://www.medsalv.com/
[295] More information on RefillNZ's water refill initiative are available at: https://refillnz.org.nz/
[296] More information on Ecostore's reuse system is available at: http://www.ecostore.co.nz/refill-stations

3.5.1 Case study: Reuse systems in global supply chains

The process of getting products and packaging to supermarket shelves is largely out of sight and out of mind for many people. However, within supply chains there is both significant use of plastic and waste. Manufacturers, retailers and the logistics and supply chain industries are uniquely positioned in that they can provide innovative solutions, including reusable systems, to reduce the waste and environmental impacts associated with moving products around the world.

A company that has demonstrated exemplary practices and innovations to improve the sustainability of supply chains is CHEP New Zealand, an arm of a multinational supply chain logistics company, which is itself a subsidiary of Brambles. The practices that could be modelled from CHEP's approach to rethinking standard supply chains include:

- **Designing solutions based on circular economy principles:** Using systems thinking to go beyond the individual components of a supply chain and instead consider how standardised pooled assets can flow through a network, reducing waste and increasing efficiency.
- **Enabling sharing and reuse over single-use:** The reusable system of plastic pallets, crates and containers reduces single-use tertiary packaging by continuously sharing and reusing assets amongst an extensive and collaborative network.
- **Using data and insights to improve efficiencies:** Combining physical platforms with cutting-edge digital and internet of things (IoT) technologies enables innovative data-driven solutions. For example, tracking temperature and other metrics through the supply chain to understand where improvements could reduce food waste and the need for packaging.
- **Aiming for zero-waste solutions:** After multiple rounds of reuse, plastic pallets can be recycled at end-of-life so that the resources stay in circulation. This supports the company's zero waste to landfill commitment. In 2018, 94% of CHEP NZ's timber pallets and 100% of their plastic crate and container service centres diverted end-of-life product from landfills.
- **Making better decisions about environmental outcomes:** CHEP design their overall system and each customer solution based on quantified environmental impacts from third-party verified LCA studies that measure carbon emissions, waste and raw material use.
- **Communicating environmental benefits:** CHEP provides customers with a certificate of recognition that quantifies their saved carbon emissions and waste based on the LCA and can be used by customers for their own environmental reporting. This highlights their contribution to progressing the UNSDGs (see Appendix 1).
- **Eradicating empty transport miles:** Using its network scale and visibility to facilitate collaborative transport solutions, CHEP brings manufacturers and retailers together to reduce the environmental impact of their operations and save money.

Rethinking and innovating supply chain logistics is a way for a company to reduce waste and environmental impact, without altering their actual product offering. CHEP's innovative model for supply chain logistics helps deliver environmental efficiencies, not otherwise available through one-way, single use alternatives, at scale. The size and reach of the network further enhances the environmental benefits associated with reuse.

3.6 Recycle

Recycling is not the only solution to our plastic problem, but it does have an important place in rethinking plastics. Without high-quality recycling streams there is no economic viability in recycling plastic due to limited market pull-through. Without a functional recycling market, the current environmental issues we face related to plastic use and waste will be ongoing. Addressing issues related to the quality of plastic that enters and leaves the recycling stream will help to establish a more stable onshore recycling market, which in turn can reduce demand for virgin plastic and reduce plastic waste to landfill.

The type of plastic ultimately dictates which (if any) method of recycling technology can be used to keep the material in circulation. In practice, product design, collection and sorting methods, and individual behaviours also determine whether a product is recycled. Traditionally we have relied on mechanical recycling techniques to keep plastic in circulation. These methods have proven to be ineffective for the majority of plastics, with estimates that globally only 9% of all plastic ever produced has been recycled.[297] In addition to innovative products, business models and materials, we can look to ways to improve current recycling practices, so that we can get the most out of the plastic materials used. We can also consider whether there is a place in Aotearoa New Zealand's new plastics economy for new processes that keep materials in circulation, such as chemical and monomer recycling, and feedstock and energy recovery (see Figure 29).

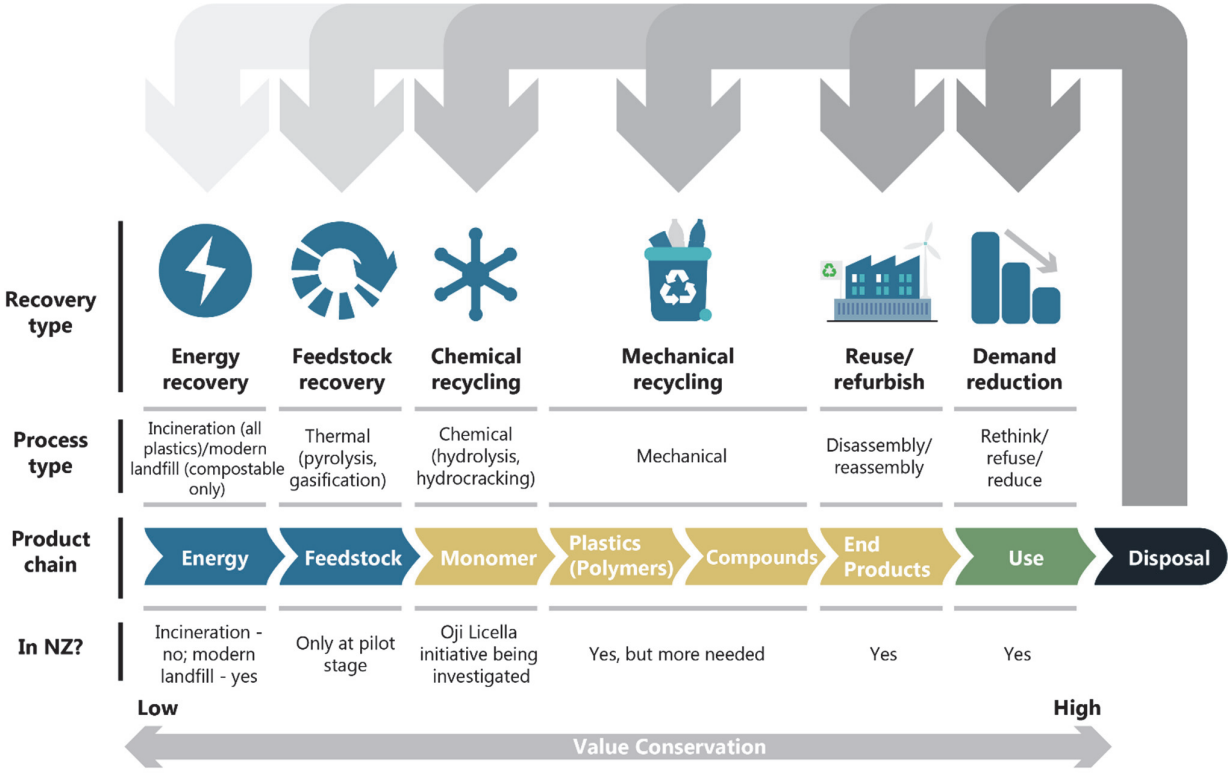

Figure 29 Different recovery techniques available. Adapted from Denmark's New Plastics Economy, McKinsey and Company

[297] Geyer et al., "Production, Use, and Fate of All Plastics Ever Made,"

In their detailed overview of the state of Aotearoa New Zealand's recycling sector in late 2018, the National Resource Recovery Taskforce (NRRT) highlighted that there are issues across the whole value chain of the current recycling system that need to be addressed in order for recycling to be a feasible solution for those plastic products that cannot be eliminated or reused.[298] As this was in response to China National Sword, the recommendations were mainly focused on packaging applications of plastics.

Taskforce recommendations from the NRRT that were accepted by the Ministry for the Environment include:[299]

1) Identifying the gaps in materials recovery and waste infrastructure where investment is needed
2) Reviewing kerbside collection and processing systems to identify how to increase the quality of recyclables and to ensure more materials can be recovered and recycled instead of going to landfill
3) Undertaking feasibility studies around how to increase Aotearoa New Zealand's fibre (paper and cardboard) processing and plastic reprocessing capacity
4) Examining how product stewardship for packaging can be used to ensure manufacturers consider what happens to packaging once a product is used by the consumer
5) Assessing the options for shifting away from low value and difficult-to-recycle plastics, such as single-use plastic bags and other low volume and/or mixed materials. This could include regulations around ensuring plastic packaging is able to be recycled and/or to require a portion of recycled content in packaging
6) Running an education campaign to help New Zealanders 'recycle right', and reduce the amount of recyclable materials going to landfill because of contamination
7) Developing model contracts for the sector to reduce contamination, increase transparency and to better accommodate fluctuations in market prices for recyclable materials
8) Developing a sustainable procurement plan and guidelines to encourage purchase of products made of recovered and recycled materials.

Here we build on the NRRT's recommendations by outlining improvements and innovations that could be implemented across the whole recycling value chain to address current issues and improve rates of recycling, as illustrated in Figure 30.

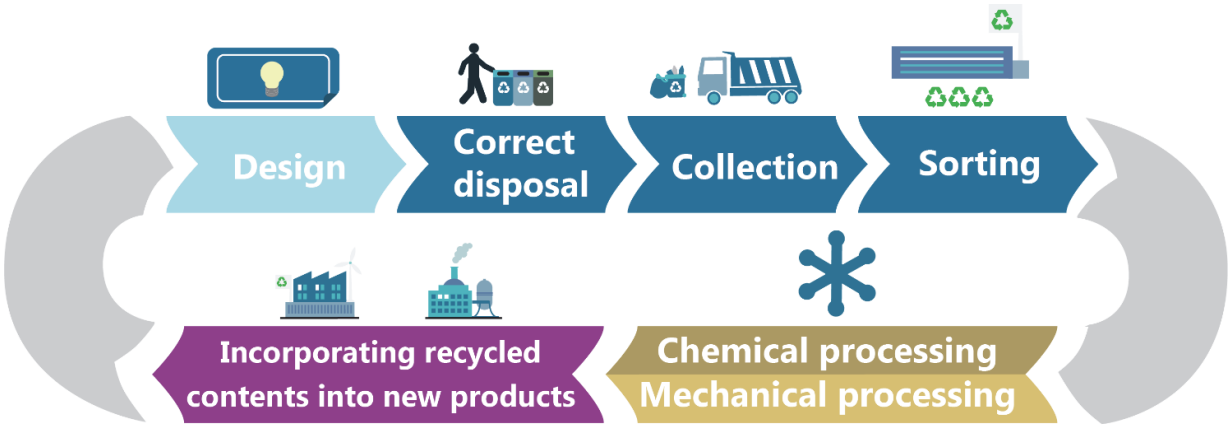

Figure 30 Areas where new systems and innovations could improve recycling

[298] Ministry for the Environment, "National Resource Recovery Taskforce: New Zealand's Options in Response to Effects Created by the Implementation of the National Sword Policy. Briefing Note", 2019
[299] Hon Eugenie Sage, "Plan to Recharge Recycling", press release, 10 May 2019, https://www.beehive.govt.nz/release/plan-recharge-recycling

3.6.1 Design for recyclability

If recycling is the desired end-of-life outcome for a product, it should be designed to ensure that it can and will be recycled in the local context. Figure 31 illustrates the types of materials that are easy (commonly collected), possible (collected in some places), and difficult-to-recycle (collected in no or few places) in the kerbside recycling systems across Aotearoa New Zealand. The value of the recycled content affects whether it is practically recycled because whether there is a market for the materials drives whether a council collects it. With current infrastructure, recycling markets and reliance on sending a significant proportion of recycling offshore, clear PET (#1) and natural HDPE (#2) have the highest recycling value; coloured PET (#1), coloured HDPE (#3), LDPE (#4) and PP (#5) are recyclable but likely to end up in a 'mixed plastics' recycling stream with low value, PVC (#3), PS (#6) also end up in a 'mixed plastic' stream in low quantities so it is difficult to find a market, and 'other' types of plastic will not be recycled and will likely contaminate other recycling streams.

Other factors aside from material choice can impact recyclability, including colour, the size of the product, the size and material of the label, and electronic tracking systems and sensors. It will also depend on whether the product is used in the household and therefore enters the kerbside recycling stream, or if it is used in a commercial setting. For example, PVC (#3) packaging is unlikely to be recycled but PVC (#3) pipes could be through various commercial recycling streams that exist locally. Best-practice guidance for businesses that includes information on how to design their products to improve recyclability is needed (as discussed in Section 2.5). Some examples of best practice that would improve recyclability through design changes are outlined in Table 15.

Figure 31 Though plastics 1-6 are all technically recyclable, the volume and market for the recycled content dictates whether councils accept these across the country. Credit: royalsociety.org.nz/plastics licenced under CC BY 3.0 NZ

Table 15 Ideas and innovations for improving the recyclability of products in Aotearoa New Zealand

Idea	Why	Limitations for implementation	Possible solutions
Avoid using coloured PET (#1), PS (#6), PVC (#3) and rigid PLA (#7). Switch to clear PET (#1), natural HDPE (#2) and PP (#5)	Onshore processing exists for clear PET (#1), natural HDPE (#2) and PP (#5) Good markets for these plastics Reduces contamination of PET (#1) recycling stream by rigid PLA (#7), PS (#6) and PVC (#3) Material able to go through multiple rounds of recycling Colour can change the flow properties of the plastic, making it less predictable in certain processes Blending different coloured plastics turns an 'icky' brown or grey colour with low or no value	Currently the cost of alternatives is cheaper Coloured packaging may be part of brand properties	Whole-of-life costs factored into PSS or CDS to drive use of recyclable material Industry-wide acceptance for level playing field
Avoid using multiple materials where they are not easily separable	Monomaterial-based products are more easily recyclable	Some products require multiple different materials because each material achieves a particular function	Clear labelling system that shows what part of product is recyclable (see Section 3.6.2) Design for disassembly by consumers Research into multilayer materials where each layer has different physical properties but same chemical composition
Label size under 60%	Optical sorters need at least 40% of the packaging to be visible to detect type of plastic	Brand willingness Size needed for mandated information Want to include recycling labelling as well with limited space	Digital barcodes for more labelling information online New sorting tech (see Section 3.6.6)
Using different packaging material if product is hard to wash off plastic	Residual contamination renders the material unrecyclable	Use of glass (which is easier to wash) increases weight which can increase transport emissions	LCA studies to understand life cycle impacts to guide choices (see Section 4.3)

3.6.2 Ease and understanding of how to recycle

To maximise opportunities for resource recovery and reuse at end-of-life, we first need to ensure that all types of plastics can be identified at end-of-life and disposed of correctly. If a plastic product can be recycled or composted, it needs to end up in the appropriate recovery system. If a plastic product can only be composted in a commercial composting facility, it must not end up contaminating the recycling stream or a domestic compost heap where it will not decompose. The complexities around how plastics are categorised are covered in Section 1.2.4. This complexity has led to general confusion in the public around the currently relied on resin ID codes and recycling symbols (see Figure 32).

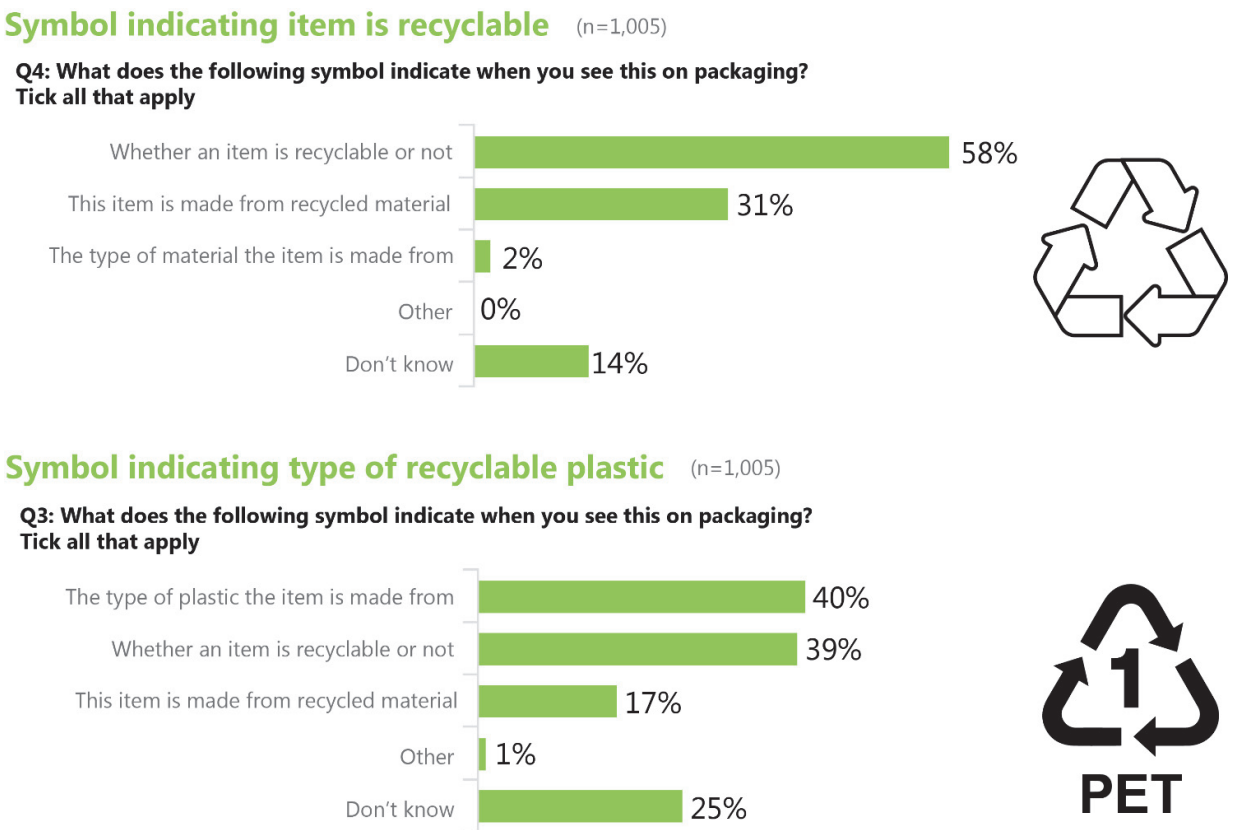

Figure 32 WasteMINZ survey responses illustrate high levels of misunderstanding for the existing recycling and resin ID codes that are used on plastic packaging. All respondents (n=1005)

At the time of publication, there were no national standards on how to categorise or label plastics in Aotearoa New Zealand. Current approaches rely on voluntary uptake and are limited in their application and effectiveness (outlined in Appendix 3). We need clearer language and symbols for plastics, including a simple recycling label that tells people whether to recycle or dispose of a product. This will improve the efficacy of recycling streams by reducing contamination of recycling streams with non-recyclable plastics (sometimes due to 'wish cycling' – where people place non-recyclable products in the recycling bin in the hope that they will be recycled), and reducing the amount of recyclable plastics ending up in landfill. There is also need for better public understanding about how to recycle correctly and the life cycle impacts of various packaging chocies. Using standard nomenclature and having clear labelling that is easy to find and read is key to facilitating best practice, particularly in the household setting for kerbside recycling and refuse. Wide adoption and public understanding is critical for success, and implementation of labelling schemes should be done in conjunction with public education initiatives. In Table 16, we highlight ideas and innovations that may be useful to help improve public understanding about plastics and help people dispose of waste correctly.

Table 16 Ideas and innovations to improve recycling efficacy through improved public understanding

Idea	Who	Examples/early adopters	Strengths	Limitations for implementation	Possible solutions
Public education	Government		Improve the quality of the materials entering the recycling stream	Current fragmentation between systems at different councils	Standardise recycling systems among NZ Councils
Physical labelling	Brand owners to apply (voluntary or regulated by Government)	Australasian Recycling Label (see Case Study 3.6.3)[300] UK on-pack recycling label (OPRL)[301]	Ready to go Can be applied to all products Doesn't rely on resin ID which is widely misunderstood If consistent with international practice may be better understood by some tourists	Regional variation in kerbside recycling Use of adhesives and different plastics for the label may contaminate recycling stream	Standardise national collection Have a standard recycling label Compliance costs may be prohibitive for small brands
Digital labelling for online shopping	Retailers	Crunch and Flourish digital packaging star[302]	Easily adaptable to different contexts Easy to update Can build on physical labelling schemes such as the ARL	More accessible via online stores, can be delivered in-store via technology and loyalty programmes Small-scale consumer testing of Packaging Star to date	Upgrade to digital price labels in store Online trial with a retailer to assess shopper behaviour

[300] More information available at: https://planetark.org/recyclinglabel/
[301] More information on the OPRL is available at: https://www.oprl.org.uk/
[302] More information available at: https://www.crunchandflourish.com/

3.6.3 Case study: The Australasian Recycling Label

The Australasian Recycling Label (ARL) is an evidence-based standardised system that provides easy to understand disposal instructions for each part of a product's packaging.[303]

The Australian Packaging Covenant Organisation (APCO) developed labelling standards with Planet Ark and PREP Design. The label includes (see Figure 33):

- The name of the package component the label refers to
- Symbols to identify whether the component is recyclable, conditionally recyclable or not recyclable
- Recyclable label has filled recycling symbol
- Conditionally recyclable label has clear recycling symbol with written instructions (e.g. return to store)
- Non-recyclable label has clear bin symbol.

Figure 33 Breakdown of components of the Australasian Recycling Label. Adapted from: www.arl.org.au.

The second phase of the ARL includes a recycled content label to help drive consumer awareness and demand for products with recycled content and a compostability label to provide much needed clarity for these products. Organisations including Australia Post, Blackmores, Nestlé, Officeworks, Unilever, Coles and Woolworths have pledged their commitment to using the label. It was introduced in September 2018 and has since been adopted by more than 200 Australian organisations.

Underpinning the ARL is the Packaging Recyclability Evaluation Portal (PREP). This analysis tool allows businesses to assess whether their product is recyclable through Australia's kerbside recycling system. By evaluating the materials used, their associated environmental impacts and local access to recycling capability, the tool allows businesses to address problematic materials throughout the supply chain and shift to packaging that is recyclable during product development and redesign. Any business that pledges their commitment to the ARL gains access to the PREP.

Part of the labelling standard relates to recycling accessibility – a product can only be labelled as recyclable if more than 80% of the population has access for that item to be recycled through their local kerbside recycling system. Packaging NZ and WasteMINZ worked with the PREP tool developers to localise the labels for the Aotearoa New Zealand kerbside recycling system. However, since this work was completed, there have been many changes to kerbside recycling across Aotearoa New Zealand in response to unstable recycling markets. This includes a number of councils restricting the plastics they accept via kerbside collection to PET (#1) and HDPE (#2). Any changes to recycling accessibility need to be reflected in the PREP tool and resulting recycling labels. Therefore, the PREP tool and ARL could be implemented in Aotearoa New Zealand, but its full potential will only be realised when the kerbside recycling system is consistent and stable.

THE PREP TOOL AND ARL COULD BE IMPLEMENTED IN AOTEAROA NEW ZEALAND, BUT ITS FULL POTENTIAL WILL ONLY BE REALISED WHEN THE KERBSIDE RECYCLING SYSTEM IS CONSISTENT AND STABLE

[303] Further details on the Australasian Recycling Label are available at: www.arl.org.au.

3.6.4 Collection

How waste is collected impacts the rates of recycling.[304] Currently in Aotearoa New Zealand, plastic is collected for recycling through household kerbside collection, public space bins, drop-off points (common in rural areas) – these are typically rate-payer funded. Other plastic is collected for recycled through commercial collections (see Figure 34). For household kerbside recycling, public space bins and drop-off points, plastic is sent to a material recovery facility (MRF) where it is sorted prior to being shipped offshore for recycling or sent to one of Aotearoa New Zealand's few onshore recycling facilities (see Case Study 3.6.8). Commercial plastic material is sometimes sent directly offshore for recycling, without need for sorting at a MRF, or is reprocessed in Aotearoa New Zealand.

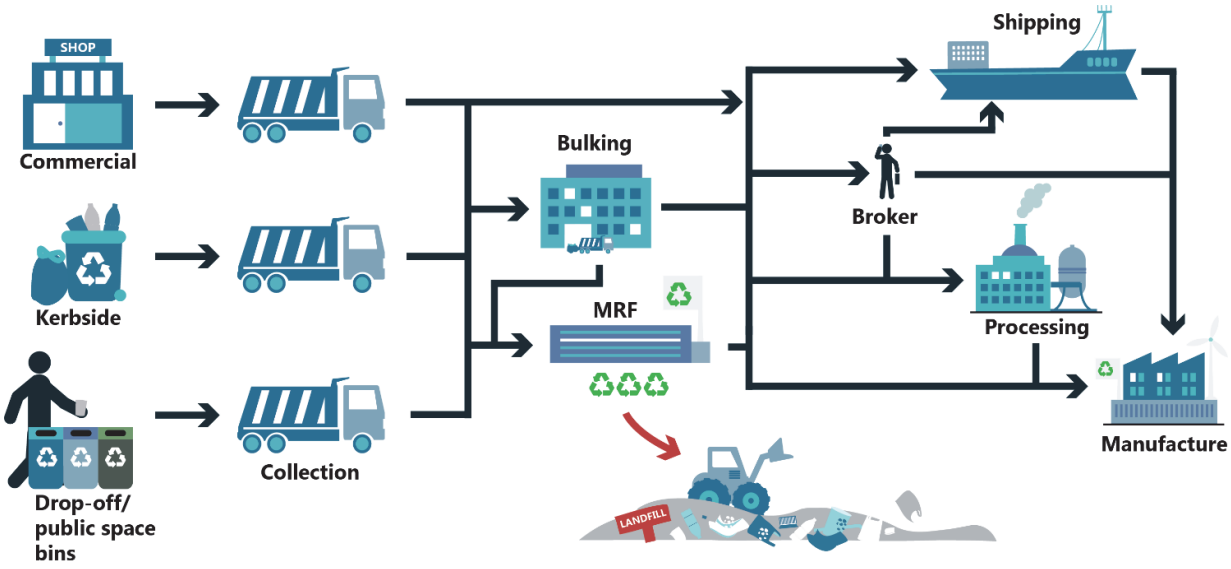

Figure 34 The current process for plastic recycling in Aotearoa New Zealand. Figure adapted from Eunomia Consulting[305]

The specific types and presentation of plastic that are accepted through kerbside collection differ by council – for example, some councils request bottle lids left on while others want them removed. Improving, standardising and expanding collection systems is necessary to increase rates of recycling. Collection points need to be easily accessible nationwide and facilitate the highest quality recycling streams. Consistency should be balanced against the needs of different regions. In Table 17, we highlight ideas and innovations that may be useful to help improve collection systems to improve recycling.

[304] Eriksen et al., "Quality Assessment and Circularity Potential of Recovery Systems for Household Plastic Waste," *Journal of Industrial Ecology* 23, no. 1 (2019)
[305] Eunomia Research & Consulting Ltd, "National Resource Recovery Project – Situational Analysis Report", 2018

Table 17 Ideas and innovations to improve recycling efficacy in Aotearoa New Zealand through improved collection

Idea	Who	Examples/ early adopters	Strengths	Limitations for implementation	Possible solutions
Standardise nationwide collection and methods for household kerbside recycling (highlighted in NRRT)	Central and local government	WRAP UK developed a framework for greater consistency in household recycling[306]	Reduces confusion around recycling practices Allows national education campaign with shared messaging	Cost barriers to align different systems falls on local government NZ's different regions may require different systems Restrictions from existing contracts and infrastructure	Support from central government to standardise Have 2-3 variations on a common system
Separate organic and inorganic waste	Local government	Stewart Island, Timaru District Council, Christchurch City Council Recology (San Francisco)[307]	Keep plastics less contaminated Opportunities to compost food waste and	Councils tied into existing contracts Carbon footprint of separate collection system may outweigh benefits Availability of green waste	Undertake an analysis to compare carbon footprint of organic waste collection vs methane collection from landfill to guide decisions
Container deposit scheme (CDS)	Central and local government	Work underway to design a scheme for NZ[308] Various states in Australia, US, and jurisdictions in EU Norwegian system (See Case Study 3.6.5)	Packaging recognised as a valuable resource Drives higher rates of recycling and generates higher quality recyclate Options for deposit exchange (cash, co-benefits e.g. transport tickets, digital tokens) Litter reduction Potential social and community benefits through fundraising, enterprise etc.	Upfront costs to implement Accessibility in regions and remote areas Adequate transition time	Implement tax for industry to support this Engage with government counterparts in places with experience in CDS (e.g. states in Australia) to understand the process to implementation and lessons learned Clearly signal implementation date well in advance to business to allow adequate transition and enable effective implementation

[306] Waste & Resources Action Programme (WRAP), "Framework for Greater Consistency in Household Recycling for England", 2016
[307] More information available at: https://www.recology.com/
[308] Hon Eugenie Sage, "Work Underway for Beverage Container Return Scheme,"

Idea	Who	Examples/ early adopters	Strengths	Limitations for implementation	Possible solutions
Product stewardship schemes (PSS) (can be voluntary, accredited or mandatory)	Government	Work underway to regulate product stewardship for some materials/ products Agrecovery[309] Plasback[310] Car bumpers[311] Public place recycling scheme[312] Child car seats[313] PVC (#3) pipes[314]	Strong support for this[315] Places value on material to be returned to system Improves quality of recycling stream Prevents hazardous streams being disposed of inappropriately Cost incorporated into upfront purchase so no extra cost at end-of-life to manage/ recover materials correctly	Difficulty designing an effective scheme that can be equitably accessed in different regions	Make mandatory or accredit Co-design scheme with industry, with variations to meet local needs Learn from international examples
Store drop-off programme for plastics not collected in kerbside collection	Industry	Soft Plastic Recycling Scheme[316]	Prevents plastics going to landfill Provides source-separation	Schemes that rely on customers to return packaging to a separate destination may not match other collection methods End markets required Need a coordinated approach across stores Providing soft plastic and compostable packaging collections at the same collection points may result in contamination	Stores who sell products offer to collect back Ensure wide and accessible distribution

[309] More information available at: http://www.agrecovery.co.nz/recycling-project-to-clear-more-waste/
[310] More information available at: https://plasback.co.nz/
[311] More information available at: https://3r.co.nz/recycling-car-bumpers/
[312] The Packaging Forum, "Public Place Recycling: Voluntary Product Stewardship Scheme ", (2016)
[313] More information available at: http://www.seatsmart.co.nz/
[314] Examples of PVC pipe schemes include SULO (see http://www.sulo.co.nz/) and Marley (see www.marley.co.nz)
[315] WasteMINZ, "Product Stewardship: What Our Members Think", 2018
[316] More information available at: https://www.recycling.kiwi.nz/solutions/soft-plastics/store-locator/

Idea	Who	Examples/ early adopters	Strengths	Limitations for implementation	Possible solutions
Store drop-off for compostable plastics	Industry	We Compost are trying to do this[317]	Mono-material streams of high quality and reduced risk of contamination of recycling streams Waste stream goes to correct infrastructure	Lack of commercial composters willing to take compostable plastics Schemes that rely on customers to return packaging to a separate destination may not match other collection methods Providing soft plastic and compostable packaging collections at the same collection points may result in contamination	Encourage brands to only use industrial compostable plastics if they have an end market for composting these Ensure wide and accessible distribution
Blockchain to support action through PSS, extended producer responsibility, community recycling[318]	Industry/ community	Empower[319] The Plastic Bank[320] Litterati[321]	Enhances business model innovation Recycling for digital payment	Lack of a coordinated approach	Policy and strategy to support new business models and community initiatives

[317] More information available at: https://www.wecompost.co.nz/
[318] Taylor, "A Rubbish Idea: How Blockchains Could Tackle the World's Waste Problem", *The Conversation*, 9 April 2018
[319] More information available at: https://empower.eco/about
[320] More information available at: https://www.plasticbank.com/
[321] More information available at: https://www.litterati.org/

3.6.5 Case study: A 97% recycling rate through a container deposit scheme

Container deposit schemes (CDS) exist in various places around the world in different forms. The highest reported rate of container recycling through such a scheme is 97%.[322] Alongside its exceptionally high return rate, Norway's CDS boasts a very high standard of materials, with 92% of bottles able to be recycled into another drink bottle.

Figure 35 A machine to collect used containers in Norway. Photo source: Elin Høyland/The Guardian

What are the features of this scheme that make it so effective?

- **A tax system that rewards high rates of collection:** The government places an environmental tax on all producers of plastic bottles. The higher the rates of the recycling, the more that tax is reduced. If producers collectively recycle more than 95%, they do not have to pay the tax. This has been achieved every year since 2011, highlighting that such a system works.
- **A level playing field that drives collaboration:** As the tax implications are shared among all products, collectively producers want high rates and high quality of recycling. Producers of bottles are better to unite and be part of one highly effective system than have fragmented approaches. More than 99% of producers of plastic bottles are part of the main scheme in Norway. They have also standardised materials to enable high rates of recycling, with producers having to use approved labels, bottle tops and glue.
- **An obligation to collect:** Every store that sells bottles is obliged to also collect them for the scheme. The flexible format of collection means that larger and smaller stores can take different approaches. Bigger stores tend to use reverse vending machines that scan, crush and pack the bottles ready for collection. Smaller stores tend to collect bottles manually over the counter. The stores benefit from a small fee per return, as well as increased footfall.
- **An easy to use and accessible system for customers:** People pay a small deposit for a bottle, depending on its size, and can return it to a machine or over the counter where they bought it for a coupon or cash. There are many thousands of sites people where can return their bottles.

Any CDS for Aotearoa New Zealand should consider Norway's CDS as a model scheme and aim to match this international best practice recovery rate.

[322] Taylor, "Can Norway Help Us Solve the Plastic Crisis, One Bottle at a Time?", *The Guardian*, 12 July 2018

3.6.6 Sorting

Sorting can happen at source and/or at the MRF, where plastic is separated out from other materials that are collected (glass, paper, cardboard) and also separated into different types of plastic. The technology at the MRF determines which types of plastic can be separated out. Some MRFs have manual sorting by pepople and others have fully automated systems. In general, plastics are separated into bales of clear PET (#1), natural HDPE (#2) and mixed bales of plastics #3-7 and coloured PET (#1) and HDPE (#2). Contaminated plastics and plastics that are not accepted at the particular MRF are removed and sent to landfill.

Systems that are more effective at sorting plastics into individual material streams will improve the recycling system by increasing the quality (and therefore the value) of the recycled content. The ultimate goal for a circular economy is that the quality of the recycled plastic means it can be used for the same product to close the materials loop. A study assessing the potential for different recovery systems in Europe to close the materials loops confirmed that higher source-separation and MRF efficiencies lead to higher recovery.[323] With current technology and raw material demands, less than 42% of the plastic loop can be closed. The potential to recycle materials is high, but factoring in the quality threshold to recover to the same quality of plastic, at best 55% of the generated plastic was suitable for recycling due to contamination. The study concluded that source-separation, a high number of different materials streams, and efficient MRF recovery were critical to close the materials loop. A study of the Dutch recycling system also identified a clear quantity-quality trade off, with a rise in the amount of plastic packaging collected for recycling leading to a larger amount of waste at sorting facilities.[324] The study highlighted the need to focus on the quality of materials received for recycling, not just increasing volumes, to close the loop on plastics.

THE STUDY CONCLUDED THAT SOURCE-SEPARATION, A HIGH NUMBER OF DIFFERENT MATERIALS STREAMS, AND EFFICIENT MRF RECOVERY WERE CRITICAL TO CLOSE THE MATERIALS LOOP

In Table 18, we highlight ideas and innovations that may be useful to help improve sorting processes to close the materials loop.

[323] Eriksen et al., "Quality Assessment and Circularity Potential of Recovery Systems for Household Plastic Waste,"
[324] Brouwer et al., "The Impact of Collection Portfolio Expansion on Key Performance Indicators of the Dutch Recycling System for Post-Consumer Plastic Packaging Waste, a Comparison between 2014 and 2017," *Waste Management* 100 (2019)

Table 18 Ideas and innovations to improve recycling efficacy through improved sorting processes

Idea	Who	Examples/early adopters	Strengths	Limitations for implementation	Possible solutions
Kerbside sort (rather than comingled)	Local government	Christchurch, Great Barrier Island	Keep plastics less contaminated May require less upfront investment	Inefficient H&S implications Cost to councils and existing contracts Environmental leakages	Public education to maximise sorting at source Best H&S practices from overseas sorting at source collection
Manual sorting at MRF	Local government/ industry	Zero Waste Raglan	Requires less upfront investment	Inefficient Finding market for sorted material, particularly smaller volumes	Resourcing issue Coordinate with other councils for economies of scale
Optical sorting	Industry	Used in some MRFs e.g. VISY in Auckland	Efficiency Accuracy	Cost-prohibitive for smaller facilities because of upfront investment Cost-prohibitive for larger facilities because of requirements for processing higher volumes Can't detect all plastics, e.g. black pigment	Support to meet upfront costs for regions Strategically invest in infrastructure around the country Design downscaled systems for smaller throughput so sorting can be done locally in regional areas Advanced tech, e.g. Unilever developed detectable black pigment so black plastics can be recycled[325]

[325] Unilever, "Unilever Pioneers Solution That Enables Black Plastic Bottles to Be Recycled", press release, 16 May 2019, https://www.unilever.co.uk/news/press-releases/2019/unilever-pioneers-solution-that-enables-black-plastic-bottles-to-be-recycled.html

Idea	Who	Examples/early adopters	Strengths	Limitations for implementation	Possible solutions
Secondary MRF[326]	Industry (supported by government)	Titus MRF in the US is piloting this approach[327]	Can achieve more mono-material streams Helps overcome NZ's issue of economies of scale for plastics in mixed plastic stream	Logistics needed to transport mixed plastics to another location (plus associated emissions from transport) Small population size may still limit economics of recycling the plastics in the mixed plastics stream	Undertake feasibility studies to determine viability of secondary MRF approach Establish plant(s) in strategic locations to be most cost-effective and minimise transport-related emissions
Marker technology/ methods for traceability of plastics	Manufacturers/ brands/ MRFs	UV tracked digital watermarks[328]	Requires fewer changes to packaging materials and labelling for brands	Requires wide acceptance across industry to be effective Cost-prohibitive	Develop international standards for new recycling methods
Use of AI and robotics for improved sorting	MRFs/ consumers	Alchemy SureSort[329] Liam the apple recycling robot[330] Zen Robotics[331] Trashbot[332] Bin-e[333] Samurai[334]	Faster, more accurate and cost-efficient sorting Potential to connect to plastic recycling value chain Small-scale operations possible	Government investment in R&D is limited Cost to implement in public infrastructure	Create an R&D investment/science challenge investment strategy around AI/Robotics and plastic waste management
Laser-assisted sorting	MRFs	Laser-induced breakdown spectroscopy	Efficient May allow for bioplastics to be collected in kerbside recycling because of ability to discriminate[335]	Cost to implement in public infrastructure Cost-prohibitive for smaller commercial operations	Strategic investment in infrastructure across country

[326] Mixed plastics can be sent to a second MRF for sorting into mono-material streams. Sorting mixed plastics from a larger number of areas will increase the streams of each of these less common types of plastic and build economies of scale.
[327] More information available at: https://titusmrfservices.net/
[328] New Plastics Economy Pioneer Project, "Holygrail: Tagging Packaging for Accurate Sorting and High-Quality Recycling", 2019
[329] More information available at: https://www.alchemysort.com/
[330] Charissa Rujanavech, "Liam - an Innovation Story", 2016
[331] More information available at: https://zenrobotics.com/
[332] More information available at: https://cleanrobotics.com/trashbot/
[333] More information available at: https://www.digitaltrends.com/cool-tech/smart-bin-e-trash-can/
[334] More information available at: http://bine.world/
[335] Jull et al., "Classification of Recyclables Using Laser-Induced Breakdown Spectroscopy for Waste Management," *Spectroscopy Letters* 51, no. 6 (2018)

3.6.7 Mechanical recycling

Mechanical reprocessing is an effective recycling method for certain types of plastic where the chemistry allows melting and reforming into new products, but it faces challenges in the current context due to there being different sources of plastic of varying quality, different types of plastic (not always identifiable) and high levels of contamination. Having higher-quality mono-material streams will naturally improve recycling markets – as addressed in Sections 3.6.1-3.6.6.

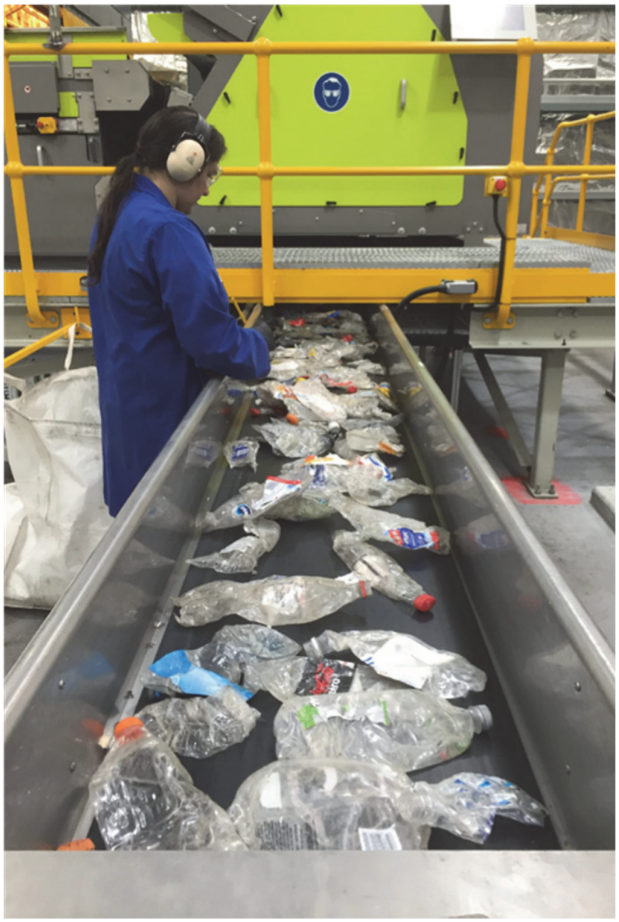

Figure 36 The recycling process at Flight Plastics in Wellington. Credit: Flight Plastics

Pre-consumer or industrial plastic waste tends to be more recyclable than post-consumer plastic waste (e.g. kerbside collections) because it is cleaner and not mixed up with other types. Specific types of plastic that are widely used in a particular industry (e.g. construction) may benefit from coordinated approaches to recycling and more accessible information about which recyclers will take certain plastic streams. These already exist for some waste streams, such as for expanded polystyrene (EPS). [336] In contrast, household waste faces greater hurdles to getting quality streams of plastic that can be mechanically recycled. For example, a commercial closed-loop system may be feasible for LDPE (#4) due to businesses having high volumes of a clean mono-material stream from secondary and tertiary packaging. In contrast, it may be less feasible to establish a closed-loop system for post-consumer LDPE (#4) (e.g. from kerbside collection) because there is not a large enough volume of clean, high-quality LDPE (#4) from this collection stream to make it economic.

Though in theory some pure plastics such as HDPE (#2) and PET (#1) are infinitely mechanically recyclable, in practice these will degrade over time.[337] However, intermixing recycled plastics with newer materials during each recycle keeps a viable pool of recycled plastic and in some markets PET (#1) has successfully been maintained in circulation for many years. In addition, additives have been developed to reduce degradation. Conversations between the panel and a variety of stakeholders suggest that with the current amounts of waste plastic and the available technology, it is only feasible to consider mechanical recycling as an option for post-consumer plastic waste for PET (#1), HDPE (#2) and PP (#5), and that infrastructure to be able to recycle these onshore is necessary. We already have more than enough capacity for closed-loop PET (#1) recycling (see Case Study 3.6.8). PET (#1) actually only accounts for around 7% of the virgin resin imported into the country (see Section 5.2). Other plastics with good recycling potential due to their chemical composition and end market are HDPE (#2) and PP (#5), which make up 26% and 18% of imported resin respectively. The focus should now be on investing in infrastructure, including sorting, to develop onshore closed-loop or durable solutions for HDPE (#2) and PP (#5).

[336] More information available at: https://greenbusinesshq.com/eps-recycling/

[337] Kealy, "Rheological Analysis of the Degradation of Hdpe During Consecutive Processing Steps and for Different Processing Conditions," *Journal of Applied Polymer Science* 112, no. 2 (2009)

WE ALREADY HAVE MORE THAN ENOUGH CAPACITY FOR CLOSED-LOOP PET (#1) RECYCLING. THE FOCUS SHOULD THEREFORE BE ON INVESTING IN INFRASTRUCTURE, INCLUDING SORTING, FOR CLOSED-LOOP OR DURABLE SOLUTIONS FOR HDPE (#2) AND PP (#5)

Plastics NZ is working with local recyclers to develop an onshore solution for PP (#5) recycling. There are examples of closed-loop recycling for HDPE (#2), such as WILL&ABLE recycling New Zealand milk bottles into cleaning product packaging,[338] but these require scaling. There are also a number of recyclers who currently recycle HDPE (#2) into durable products, but current infrastructure does not allow for closed-loop recycling for food grade materials or detergent grade materials. HDPE (#2) that is used in packaging for food and drinks has different requirements to HDPE (#2) used in cosmetics and detergents. For example, food-grade recycled content has to meet food-safety standards and the environmental stress crack resistance needed for detergent-grade HDPE (#2) is higher because of the longer use of the packaging. Keeping these streams separate may lead to higher yield closed-loop solutions for respective streams and should be considered when estimating material flows.

At present, there are some mechanical recycling solutions for soft plastics collected in the Soft Plastic Recycling Scheme that mix these materials with HDPE (#2) to form new products, such as fence posts.[339] The soft plastics are the filler for these new materials – it is not a circular solution, but it could be argued this reprocessing gives these materials a longer life than through recycling as they are incorporated into durable products. Soft plastics require further onshore solutions, which may go beyond mechanical recycling. For example, there may be some applications where it is better to use compostable soft plastic packaging rather than relying on packaging being recycled.

Innovative approaches are needed to improve the quality of the materials that are mechanically recycled onshore. In Table 19 we outline technologies that may be able to improve the efficacy of mechanical reprocessing. Government can work with industry to establish new infrastructure onshore to process plastics, based on a shared action plan. Scion's New Plastics Economy Roadmap project will develop this further.[340]

[338] More information available at: https://willandable.co.nz/
[339] There are no data on whether these applications will leak microplastics in the longer term.
[340] Scion, "Plastics Nz Awards and Launch of Plastics Roadmap,"

Table 19 Ideas and innovations to improve recycling rates through mechanical recycling

Technology/ idea	Who	Examples/early adopters	Strengths	Limitations for implementation	Possible solutions
Wash-off adhesive	Brand owners	RW85C for PET (#1) containers[341]	Can undergo common PET (#1) recycling processes without contaminating the recycling stream	Cost Practicality of wash-off adhesive in humid and chilled environments where condensate is common	Financial incentives or regulation for all to use
New applications for mixed plastic recycling[342]	Industry	Plazrok (see Case Study 3.6.9) EcoGlobal[343] FuturePost[344] Building blocks (ByBlocks by ByFusion[345]) Roads	Uses otherwise non-recyclable plastics, and reducing waste to landfill	Possible safety issues with potential leach or out-gas toxic additives, or leaching microplastics, depending on application and feedstock Not a closed material loop Requires a system or scheme for products to be recovered at end-of-life	Rigorous environmental testing and ongoing monitoring before application Expert peer review of technology before it can be used
Textile recycling	Recyclers	Econyl - Regenerated nylon from waste for fashion and interior industries Worn Again Technologies[346]	Reduces landfill waste Provides economic opportunities for commercial and not-for-profit organisations	Cost Quality – aesthetics and functionality may be reduced through mechanical processing, difficult to reprocesses mixed fibre textiles	Financial incentives to develop infrastructure onshore R&D Design for remanufacture initiatives

[341] More information available at: https://go.upmraflatac.com/RW85C
[342] New products have been developed that take advantage of plastics' durability while not needing to have the same appearance and strength properties of virgin plastics.
[343] Jonhson, "Seeking a Greener Option for Film Recycling", *Plastics News*, 7 March 2019
[344] More information available at: https://www.futurepost.co.nz/
[345] More information available at: https://www.byfusion.com/the-blocker/
[346] More information available at: http://wornagain.co.uk/

3.6.8 Case study: Developing onshore closed-loop mechanical recycling solutions

In 2017, Flight Plastics established the first closed-loop mechanical recycling system in Aotearoa New Zealand for PET (#1), producing clear recycled PET (rPET) containers that, due to food hygiene standards, include a thin layer of virgin PET as the lining. The rPET containers produced by Flight Plastics are themselves recyclable several times via the same recycle loop. Plastic drink bottles are the main use of PET, and consequently make up the main volume of post-consumer PET recycled material collected and sorted in Aotearoa New Zealand. Flight uses this material to produce food-grade rPET trays and containers, which directly reduces the volume of virgin PET previously imported for this purpose. The year Flight Plastics established onshore processing for PET, more than 17,500 tonnes of virgin PET was imported into Aotearoa New Zealand, with roughly 5,000 tonnes of clear PET collected for recycling. Flight's start-up year processed limited volume during plant commissioning and trials, but the following year the amount of virgin resin imports had decreased by roughly 1,600 tonnes. This was the first-time virgin PET imports had fallen for more than a decade, and demonstrates the clear and immediate impact of onshore waste plastics recycling and reuse. Flight expects to process close to 5,000 tonnes of rPET in 2020 and a similar volume of virgin PET import reduction will occur accordingly (subject to overall market demand).

The Flight Plastics plant is now recycling almost all of the clear post-consumer PET currently collected and available in the market (some is still exported) and has spare capacity to recycle at least 50% more before further capacity is required. As a result, it can be said that Aotearoa New Zealand now has infrastructure to deal with all of the PET being recycled currently, and has the capacity to deal with a growing volume of PET as rates of recycling increase as expected with the implementation of a container deposit scheme (CDS), and as businesses shift away from problematic plastics such as PVC (#3) and PS (#6) to this more sustainable plastic.

In future, recycling methods for this material may need to be able to generate bottles. New infrastructure is being considered for Flight's plant to achieve this, but in the immediate term all of the available material is being fully utilised in a genuine circular economy loop for containers. PACT Group in Auckland are also establishing PET reprocessing capabilities and will convert 10,000 tonnes of PET a year into food packaging, including meat and bakery trays, but will supplement with imported rPET material pending availability of local recycled PET.[347]

Lessons from Flight Plastics' experience can guide efforts to establish onshore solutions for HDPE (#2) and PP (#5). A key challenge faced while establishing onshore reprocessing capabilities is the low recycling rate, which limits the amount of recycling that can be undertaken. For example, less than 30% of imported PET resin is recycled – meaning that a large percentage of this valuable, recyclable plastic is still ending up in the landfill or the environment. In order to make reprocessing economic, the design, disposal, collection and sorting methods need to be improved to increase recycling rates. Because the investment returns in recycling are generally very low, companies making large and long-term recycling investments face considerable risk in a volatile and competitive market. This is heightened by the local market having to compete against imported recycled resin. Regulation to incentivise the use of recycled content would strengthen the markets for these materials. If further incentives exist for local recycled content, it would do more to strengthen the local recycling industry. Lastly, the reprocessing infrastructure is only part of the set-up cost. It is important to factor in extra costs up and downstream of the recycling process when establishing and funding new infrastructure to develop onshore closed-loop solutions for HDPE (#2) and PP (#5).

[347] Lewis, "How the New Circular Bio-Economy Could Deal with the Problem of Plastic", *The Listener*, 23 October 2019

3.6.9 Case study: Using mixed plastics in new materials

There are an increasing number of initiatives worldwide that are using waste plastic as components of building and construction materials. Incorporating plastics into roads is becoming more commonplace, with examples and various techniques used in Indonesia, India, Australia, the UK and most recently in New Plymouth.[348]

Figure 37 Aggregate made with Plazrok™ Source: https://enviroplaz.com/plazrok/

A similar type of chemical transformation has been adopted by Enviroplaz International Ltd, who have their Head Office in Wiri, to produce an aggregate substitute to make superior-grade concrete using plastic waste feedstock.[349] Its particular advantage is the ability to use mixed plastic – all types 1 to 7, unsorted and unwashed – most of which would otherwise be landfilled.

Plazrok™ is a lightweight composite aggregate, manufactured from mixed waste plastic, to be used as an additive for a range of concrete applications. The manufacturers cite that concrete made with Plazrok™ can be manufactured between 10–40% lighter than traditional stone aggregate and has similar mechanical properties, which leads to reduction in transport costs and emissions to the construction site. It also has potential advantages in terms of ability to flex.

The material can be recycled and its main applications would be tilt up slabs and non-structural elements of high-rise buildings. It is currently undergoing independent tests to provide assurance of its properties. Applications of mixed plastic waste into building and roading materials need to be accompanied by robust testing of the environmental and health impacts associated with these materials in the short and long term, particularly related to the chemical additives in the plastics (see Section 4.14) and possible contribution of microplastics into the environment (see Section 4.15).

[348] Satherley, "The Kiwi Town Making Roads out of Plastic", *Newshub*, 7 June 2019
[349] More information available at: https://enviroplaz.com/plazrok/

3.6.10 Chemical recycling

Several new chemical recycling technologies, some drawing on the principles of green chemistry,[350] are emerging that address limitations in materials composition and mechanical recycling processes. Chemical recycling techniques may be able to keep previously unrecyclable plastics and lower-quality recyclable plastics in circulation. Some techniques can process mixed plastics and others can generate high-value recyclate from a material that would only generate low-value recyclate through mechanical recycling.

CHEMICAL RECYCLING TECHNIQUES MAY BE ABLE TO KEEP PREVIOUSLY UNRECYCLABLE PLASTICS AND LOWER-QUALITY RECYCLABLE PLASTICS IN CIRCULATION

Chemical recycling usually uses some combination of high temperatures, pressures, solvents and reagents to transform plastics into simple organic compounds, including the constituent monomers from which the polymers were made, small-chain hydrocarbons, and/or petrochemical feedstocks. Remaking the original polymer from the constituent monomers obtained this way is generally seen as a particularly circular method because it enables the same grade and type of polymer as the original to be formed from the waste plastic material, albeit with less than 100% yield. The new polymers formed this way are usually indistinguishable from the virgin polymers and can be used for food applications, which could help to address some of the food-safety concerns associated with using recycled plastic from mechanical recycling. The related process of conversion converts plastics into fuels or petrochemical feedstock that can be fed into refineries or chemical plants, respectively.[351]

Because chemical recycling can create high-quality recycled plastic and maintain value for the material that may be lost if mechanically recycled, it will be necessary to increase overall rates of recycling and fill the strong demand for recycled resin, which cannot currently be met with existing mechanical infrastructure and technology (see Case Study 3.6.11).[352] This strong demand is illustrated by Loop, a Canadian PET (#1) chemical recycling start-up, and Indorama, the world's largest PET (#1) manufacturer, roughly doubling the capacity of their first PET (#1) chemical recycling facility because capacity was fully subscribed by customers, who include Danone, PepsiCo and Coca-Cola.[353]

There are currently no chemical recycling facilities in Aotearoa New Zealand. Oji Fibre Solutions has publicly stated they are working with iQ Renew and Licella to investigate an onshore chemical recycling solution using the Cat-HTR™ technology, which they cite is ready to move from the pilot phase to commercial roll-out.[354] This catalytic hydrothermal reactor technology uses water at near super-critical temperatures to reverse chemical bonds not possible at lower temperatures. Additional investigations into onshore chemical recycling options are underway but not public. In Table 20, we highlight the chemical recycling technologies that may be applicable to close the loop on materials.

Zero Waste Europe recently published a report outlining the state-of-play and policy challenges related to chemical recycling.[355] The report describes pilot plants for different techniques and highlights that only limited information about the environmental performance of chemical recycling technologies as a whole is available and further research is required, especially for techniques that use organic solvents. Chemical recycling is an active area of research. For example, the US National Science Foundation has 'Engineering the Elimination of End-of-Life Plastics' as a topic for their Emerging Frontiers in Research and Innovation (EFRI) program for 2020.[356]

[350] More information available at: https://www.rsc.org/journals-books-databases/about-journals/green-chemistry/
[351] Boston Consulting Group, "A Circular Solution to Plastic Waste", 2019
[352] The Recycling Partnership, "The Bridge to Circularity: Putting the New Plastics Economy into Practice in the U.S.", 2019
[353] Paben, "Facility to Depolymerize up to 88m Pounds of Pet Annually", *Plastics Recycling Update*, 16 October 2019
[354] Oji Fibre Solutions, "Oji Fibre Solutions Teams up on Plastic Recycling Technology", press release, 2 August 2019, http://business.scoop.co.nz/2019/08/02/oji-fibre-solutions-teams-up-on-plastic-recycling-technology/
[355] Zero Waste Europe, "El Dorado of Chemical Recycling: State of Play and Policy Challenges", 2019
[356] National Science Foundation, "Nsf Announces Fy 2020 Efri Topics", press release, 17 April 2019, https://www.nsf.gov/news/news_summ.jsp?cntn_id=298348&org=EFMA

The conclusions drawn in the Zero Waste Europe report that are also valid for the Aotearoa New Zealand context are:

- If closing the materials loop is the focus of Aotearoa New Zealand's future plastic system, regulation will be required to ensure that chemical recycling technologies are used to do this rather than create energy or fuel
- Excessive emphasis on chemical recycling as a solution to the current issues with the plastics economy risks encouraging the status quo with plastic use and could undermine efforts to shift approaches to plastic use up the waste hierarchy
- Chemical recycling is not a 'now' solution at an industrial scale. Most plants are only in pilot stage and industrial-scale roll-out is not expected until 2025 or later. Therefore, decisions around which technologies have a place in Aotearoa New Zealand's future plastics system need to factor in the drive to reduce use of non-recyclable plastics by 2025
- If chemical recycling technologies are landed on as a solution, we need to ensure that these are aligned to the quantities and types of plastic that we expect from 2025 onwards. For example, coloured PET (#1) has low value as recycled plastic because it turns grey when different colours are mixed. Some chemical recycling techniques may be able to address this by removing the colour and creating virgin-quality, clear PET (#1), which has strong demand. But the need for technology to address coloured PET (#1) may be displaced by brands shifting to clear PET (#1), which is more likely to be recycled in the local content, prior to commercial-scale facilities being established
- Chemical recycling should be used to deal with degraded, coloured and contaminated plastics and never with high-quality plastics coming from separate collection.

CHEMICAL RECYCLING IS NOT A 'NOW' SOLUTION AT AN INDUSTRIAL SCALE. MOST PLANTS ARE ONLY IN PILOT STAGE AND INDUSTRIAL-SCALE ROLL-OUT IS NOT EXPECTED UNTIL 2025 OR LATER

Table 20 Ideas and innovations that use chemical recycling technologies

Technology	Examples/early adopters	Strengths	Limitations for implementation	Possible solutions
Controlled thermal depolymerisation (pyrolysis) Processing back to monomers using high temperatures	Cat-HTR™ technology (catalytic hydrothermal reactors):[357] Oji Fibre Solutions and iQ Renew looking at this for NZ[358] Diagen (Solray Systems): Continuous hydrothermal conversion of biomass into liquid hydrocarbon fuels[359] COMY Environmental NZ Ltd: Start-up with exclusive right to patent and technology from parent company in China (Zhejiang COMY Energy Tech). System can take plastic types 2, 4, 5, 6 and 7[360] Eneform in Christchurch plan to process tyres into oil and gas fuels from 2020, adding plastics later[361] Renewology uses a pyrolysis technology to convert low-grade plastics into fuel and petrochemical feedstocks[362] Enval (UK) has a process than can recycle plastic aluminium laminates[363]	Most suitable for easily mechanically recycled plastics PET (#1) and PP (#5) and better with mono-material streams, but can take mixed plastics and plastics that are not easily mechanically recycled Decontaminates polymers Doesn't face degradation issues Can be reprocessed to form new plastics if conditions are right, but more likely fuels and other hydrocarbon feedstocks	Needs sustained and consistent amount of feedstock May not be economically viable due to small population and large geographical distances with poor rail connectivity – requires scale but is costly Not 100% yield Requires regular maintenance Downtime is expensive May still require sorting and cleaning Plastic to fuel technology may not close materials loop Energy intensive process	Undertake economic analysis to determine viability for NZ Technological developments enabling effective small scale distributed approaches Regulate to ensure technology used to close materials loop Use for specific materials e.g. LDPE (#4) film

[357] More information available at: https://renewelp.co.uk/
[358] Oji Fibre Solutions, "Oji Fibre Solutions Teams up on Plastic Recycling Technology,"
[359] More information available at: https://www.solraysystems.co.nz/the-technology/
[360] Start-up in NZ with exclusive right to patent and technology from parent company in China (Zhejiang Comy Energy Tech). System can take plastics 2, 4, 5, 6 and 7
[361] More information available at: http://eneform.com/
[362] More information available at: http://renewlogy.com/
[363] More information available at: http://www.enval.com/

Technology	Examples/early adopters	Strengths	Limitations for implementation	Possible solutions
Gasification[364] Processing back to syngas (a mixture of carbon monoxide, carbon dioxide and hydrogen)	Sekisui Chemicals (Japan)[365]	Can take mixed plastics and other waste	May not close materials loop Energy intensive	Local studies and trials to determine if suitable
Chemical depolymerisation Processing back to monomers or intermediates using chemicals	Existing pilot plants for PET (#1), PU, PA[366] BP developing pilot plant in the US in 2020 for lower-value PET (#1) scrap[367]	Decontaminates plastic and removes additives and colours Plastic can be processed infinitely and produces virgin-quality plastic Fewer issues around varied quality of input plastics Can be used for low quality and coloured plastics that are problematic for mechanical recycling	Cost – significantly more expensive than mechanical recycling Only works with monostreams (PET (#1), PU, PA, PLA, PC, PHA, PEF) and need to remove as much contamination as possible Don't fully understand environmental and systemic impacts of this on yield, leftover by-products and chemical safety of catalysers that are sometimes needed for reaction	Further research needed around safety Local trials prior to scale-up
Solvent-based purification Uses solvents to process plastic back to polymers	PureCycle technologies[368]	Results in high yields of recovered polymer Decontaminates plastic by removing additives and dyes and deals with residual contamination New plastics can be used for food packaging Can help recover polymer from multi-layer packaging	Cost – solvents can be expensive and costs more with more mixed materials, may require other infrastructure Output quality depends on input quality and process parameters – better with mono-material streams (PVC (#3), PS (#6), PET (#1), PP (#5)) and cannot improve degraded plastics	Financial incentives; R&D support Collection that supports mon-material streams

[364] For a review, see: Lopez et al., "Recent Advances in the Gasification of Waste Plastics. A Critical Overview," *Renewable and Sustainable Energy Reviews* 82 (2018)
[365] More information available at: https://www.sekisuichemical.com/whatsnew/2017/1325318_29675.html
[366] Zero Waste Europe, "El Dorado of Chemical Recycling: State of Play and Policy Challenges", 2019
[367] BP, "Bp's New Technology to Enable Circularity for Unrecyclable Pet Plastic Waste", press release, 24 October 2019, https://www.bp.com/en/global/corporate/news-and-insights/press-releases/bp-new-technology-to-enable-circularity-for-unrecyclable-pet-plastic-waste.html
[368] https://purecycletech.com/

3.6.11 Case study: A model to sort a whole country's plastic waste

The evidence that only 9% of plastic produced to date has been recycled highlights that we cannot rely solely on existing recycling practice to fix our plastic problem.[369] Most countries have some existing infrastructure to support mechanical recycling, but there is a lack of evidence around the other infrastructure that would be effective and economically viable to support the shift to a new plastics economy. To understand what the best infrastructure and methods to deal with plastic waste were, Recycling Technologies modelled Scotland's household plastic waste. The Project Lodestar model compared material flows, yields, economics and environmental impacts for mechanical recycling alone versus three different types of facility that had mechanical and chemical recycling.

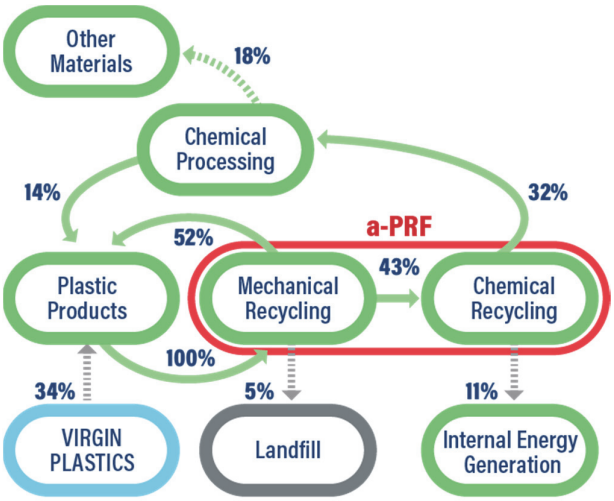

Figure 38 Modelled material flows in an advanced polymer recycling facility (aPRF) as determined in the Project Lodestar study. Image credit: recyclingtechnologies.co.uk

The model found that for Scotland's amount and composition of household plastic waste, using chemical recycling to keep non-mechanically-recycled plastic materials in the economy could bring an economic advantage over incineration and landfilling. Compared to mechanical recycling alone, modelling suggests that a facility with both mechanical and chemical reprocessing capabilities could increase revenue by 25% and decrease the payback time of the facility by 11%. This demonstrates the potential feasibility of an 'all plastics' sorting and recycling facility that uses both mechanical and chemical recycling.

THE MODEL FOUND THAT FOR SCOTLAND'S AMOUNT AND COMPOSITION OF HOUSEHOLD PLASTIC WASTE, USING CHEMICAL RECYCLING TO KEEP NON-MECHANICALLY-RECYCLED PLASTIC MATERIALS IN THE ECONOMY COULD BRING AN ECONOMIC ADVANTAGE OVER INCINERATION AND LANDFILLING

The findings depended on the presence of landfill taxes and gate fees for incineration. Therefore, to understand the type of facility that would best support the transition to a new plastic economy for Aotearoa New Zealand, a similar model could be established based on the amount and composition of household waste, building in the costs and systems of our local context. The project also highlighted that reprocessing infrastructure alone is insufficient to improve recycling rates – packaging redesign, phasing out problematic types of plastic packaging, and a comprehensive and effective collection system are all essential parts of the equation.

A more detailed case study is available on the New Plastics Economy website.[370]

[369] Geyer et al., "Production, Use, and Fate of All Plastics Ever Made,"
[370] The full case study for Project Lodestar is available at: https://www.newplasticseconomy.org/assets/doc/Lodestar.pdf

3.6.12 Case study: Controlled plastic decomposition

Plastics are made by joining monomers together to form long flexible chains in a process known as polymerisation.[371] The strength of the bonds formed between monomers is what makes the plastics persistent in the environment. Chemical recycling relies on using chemical action at high temperatures or in organic solvents, to break the bonds at the end of the product's life so that the monomers can be recovered and used to make new plastic.[372]

Biodegradable plastics (e.g. PHAs, described in Section 3.7) are made using bonds that are similar to those found in natural materials and so are able to be broken by microbes in mild conditions. These processes are controlled within the microbe by enzymes, which enable the chemistry to take place in environmental conditions. One of the attractions of PHA is that it is derived from bacteria, which means naturally occurring microbial enzymes are well equipped to break it down efficiently in the environment at the end of its useful life.

A long-term solution to the decomposition of non-biodegradable plastic might be found by building on exciting new science aimed at engineering enzymes, or selecting microorganisms, that can digest traditionally non-biodegradable plastic in environmentally friendly conditions. For example, in recent high-profile papers a major step forward was reported in which the authors describe enzymes that can decompose PET (#1) by breaking it down into its constituent molecules by hydrolysis.[373] The enzymes were isolated from a microbe that shows some ability to degrade PET (#1).[374] This represents an excellent first step towards a bioengineering solution for the removal of plastic waste. The work builds on an increasing body of literature in this field (for a review, see Kawai et al.[375]) and is an avenue of research that holds promise for a revolutionary new approach to use microbes or enzymes to address limitations in the chemistry we rely on today by having potential to degrade macro-, micro- or nano-plastics in the environment.

Despite attention grabbing headlines – 'Are plastic eating enzymes the planet's only hope?'[376]; 'Mutant Enzyme Gobbles up Plastic'[377]; and 'A mutant plastic eating enzyme could help solve the world's waste problem'[378] – there is a very long path from this initial exciting result to a practical solution. The significant advance is so far restricted to decomposing PET (#1) – probably the easiest of the plastics to recycle. One of the biggest difficulties with enzyme degradation of plastics is getting the plastic into solution so the enzyme can degrade it. However, with deeper understanding and increased focus, there is long-term hope that organisms might be discovered or engineered to disassemble other plastics.

Researchers in Aotearoa New Zealand are also becoming interested in this new idea, with a team at Auckland winning a recent MBIE Endeavour grant 2019-2022 to explore this field – focused on engineering a heat stable version of the protein[379] – and the MBIE Endeavour Aotearoa Impacts and Mitigation of Microplastics project 2018-2023 including bioprospecting of potential degraders from marine and wastewater environments.

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[371] Royal Society Te Apārangi, "Plastics in the Environment: Te Ao Hurihuri – the Changing World", 2019
[372] Christensen et al., "Closed-Loop Recycling of Plastics Enabled by Dynamic Covalent Diketoenamine Bonds," *Nature Chemistry* 11, no. 5 (2019)
[373] Palm et al., "Structure of the Plastic-Degrading Ideonella Sakaiensis Mhetase Bound to a Substrate," *Nature Communications* 10, no. 1 (2019)
[374] Yoshida et al., "A Bacterium That Degrades and Assimilates Poly (Ethylene Terephthalate)," *Science* 351, no. 6278 (2016); Palm et al., "Structure of the Plastic-Degrading Ideonella Sakaiensis Mhetase Bound to a Substrate,"
[375] Kawai et al., "Current Knowledge on Enzymatic Pet Degradation and Its Possible Application to Waste Stream Management and Other Fields," *Applied Microbiology and Biotechnology* 103, no. 11 (2019)
[376] Shields, "Are Plastic-Eating Enzymes Our Planet's Only Hope?", *howstuffworks.com*, 17 September 2019
[377] Patel, "Mutant Enzyme Gobbles up Plastic", *Anthropocene*, 19 April 2018
[378] "A Mutant Plastic-Eating Enzyme Could Help Solve the World's Waste Problem", 6 June 2018
[379] MBIE 2019 Endeavour Round Successful Projects available at: https://www.mbie.govt.nz/assets/2019-endeavour-round-successful-projects.pdf

3.6.13 Incorporating recycled content into new products

One of the conceptually simplest ideas to improve the effectiveness of recycling systems is the use of recycled plastics to make new product that can then be recycled. This prevents use of landfill, and release of further carbon from fossil-fuel sources. As people have become more conscious of the damage done by plastics in the environment, companies have begun to incorporate the use of recycled products as part of their branding.

Figure 39 Ecostore made a line of bottles from 100% recycled ocean waste plastics. Photo credit: Ecostore.

The key issues that need to be addressed to increase incorporation of recycled content into new products are:

- Ensuring that use of recycled plastics in food packaging does not cause food safety risks (via chemicals or contaminants – see Section 4.14)
- The unstable recycled plastic market
- The drop in strength and appearance through cycles: though in theory certain plastics are infinitely recyclable, in practice materials will reach their end-of-life, particularly with mechanical recycling, and require disposal at some point
- Using lower quality, i.e. not 100% pure, recycling streams requires innovations in processing methods to account for the different properties and variations in the plastic raw material (e.g. chemical recycling technology see Section 3.6.10).

Innovations and ideas to improve incorporation of recycled content into new products are outlined in Table 21.

Table 21 Ideas to increase the use of recycled content in new products

Technology	Who	Examples/early adopters	Strengths	Limitations for implementation	Possible solutions
Boost demand through government procurement and targets[380]	Government	New government procurement rules (rule 20)	Strengthens market for recycled plastics	Infrastructure for quality recycled plastics Difficulty identifying products that have recycled content	Create a resource that identifies local products with recycled content
Labelling to promote recycled content	Brands	ARL to include this in phase 2 (see Case Study 3.6.3) Ecolabel	Consumer appeal	Ecolabel doesn't include single-use plastics	Implement ARL

[380] More information available at: https://www.procurement.govt.nz/broader-outcomes/

Technology	Who	Examples/early adopters	Strengths	Limitations for implementation	Possible solutions
Mandate use of recycled plastic	Government	California bill (stalled)[381] UK (Wales and Scotland) – Taxing products with <30% recycled products and bringing in CDS	Strengthens market for recycled plastics Evens the playing field so early adopters not disadvantaged	Requires importing recycled resin with current limited infrastructure Slower to implement Need to factor in food safety issues which may require virgin layer	Could be achieved in product stewardship schemes for packaging Send signal to business of date when implemented for transition period Phase in targets with development of onshore processing and market creation
Implement targets	Government/ Industry	NZ Plastics Packaging Declaration and New Plastics Economy Global Commitment[382] APCO and UK Plastics Pact targets of 30% average recycled content for packaging by 2025[383]	Simplicity	Hard to control imports Uptake may be limited unless mandated	International agreements Explore international product stewardship as part of trade agreements e.g. CPTPP
Industry working groups to establish market for recycled plastic	Industry	Post-consumer recycling of PP (#5)[384] NEMO (new end market opportunities) US initiative Recycling Demand Champions (See Case Study 2.4.3)	Quick to implement Continue to signal strong demand for recycled material	When recycled resin has a higher price than virgin it may limit voluntary uptake	Establish a pact or industry working group to support issues of market pull through by connecting groups (could connect to existing pledges)

[381] Staub, "Recycled Plastic Mandate Advances in California", *Plastics Recycling Update*, 24 April 2019 Note: this has been stalled.
[382] Ellen MacArthur Foundation, "The New Plastics Economy Global Commitment ", 2017
[383] "Business and Government Unite to Tackle Waste Challenge", press release, 26 September 2018, https://www.packagingcovenant.org.au/news/business-and-government-unite-to-tackle-waste-challenge and http://www.wrap.org.uk/content/the-uk-plastics-pact
[384] Paul Mitchell, "Palmerston North Pipe-Maker Recycling 25 Tonnes of Plastic a Month in New Partnership", *Stuff*, 25 February 2019 and Gibb, "Praise for Public Plastic Recycling Trial", press release, 26 February 2019, https://www.odt.co.nz/business/praise-public-plastic-recycling-trial

Technology	Who	Examples/early adopters	Strengths	Limitations for implementation	Possible solutions
Blockchain/ big data	Industry/ Government	Enevo[385]	Transforming waste management into a data driven and demand-based model Utilisation of predictive analytics, performance analysis, accuracy of measurement Transparency of the plastic waste value chain, enhances business model innovation	Fragmented regional collection policies Cost to public infrastructure	National plastic waste management system
Innovations to recycle ocean plastics	Business	Clothing, e.g. Girlfriend[386] and Adidas[387] Ecostore ocean plastics range Coca-Cola developed proof-of-concept bottle with 25% ocean plastics[388] Formway designs chair[389]	Potential for sustainability label to add consumer appeal	Market size Potential contamination issues may limit use in food and drinks packaging	Partner with international initiatives Assess risks of using these in food packaging and pending results, limit to certain applications if necessary

[385] More information available at: http://www.europarl.europa.eu/cmsdata/103427/4_enevo.pdf
[386] More information available at: https://www.girlfriend.com/
[387] More information available at: https://www.adidas.co.nz/search?q=parley
[388] Coca-Cola, "Breakthrough Technology Takes Plastic from the Ocean and Uses It in a Coca-Cola Bottle", press release, 3 October 2019, https://www.businesswire.com/news/home/20191003005139/en/Breakthrough-Technology-Takes-Plastic-Ocean-Coca-Cola-Bottle
[389] More information available at: https://noho.co/

3.7 Replace

Plastics are so widely used because they are cheap, light, durable and waterproof, and can be impermeable to air. This mixture of properties was not found in the natural materials available before the development of plastic and led to their rapid uptake by manufacturers and consumers.[390] The major drawbacks of plastics are the toxic compounds that are sometimes added during their formulation, their persistence in the environment – an unintended consequence of their durability – and the fact they are sourced from fossil fuels.

While we can return to the use of pre-plastic era materials such as glass, paper, wood and steel, they have disadvantages. For example, glass is durable and air-tight, but heavy and manufacture has a high energy intensity; paper is light and cheap, but mostly not waterproof. Materials science offers the promise of new polymeric materials that can solve these problems, which are also fit for purpose and more sustainable.

The long-term goal is to develop and use a suite of new materials that are bio-based, biodegradable, sustainably produced and able to fulfil a wide range roles including packaging application. In the short-term, there are priority areas for innovation to replace particularly problematic materials. These include:

- Foils/laminates
- Synthetic fabrics that shed microfibres
- Difficult-to-recycle plastics used in packaging (PVC (#3), PS (#6) and various resins that fall into the 'other' category).

Any introduction of new plastics or alternative materials needs to be guided from a system perspective.[391] There are several particularly important considerations when introducing new materials to replace the problematic plastics we currently use:

- **Is it safe?** All new materials or new applications of existing materials need to have their safety profile tested. This is particularly true of new materials made from recycled plastic, as chemical additives may be carried into a new product depending on the quality or method of recycling (e.g. mechanical or chemical).
- **Is this a better alternative for the environment?** The environmental impacts from the whole life cycle of the product should be considered, including any reductions in preservation of the product, to assess how these differ and whether the new material is better than the plastic being replaced (discussed in Section 4.3). Environmental impacts may be further reduced if the material can be reused multiple times before being recycled.
- **What might the unintended consequences be?** Lessons can be learned from the example of bisphenol-A (BPA) – an industrial chemical that is a common component of and additive to plastics and resins. Of roughly 30 chemicals that have been used to replace BPA, almost none are demonstrably safe.[392]
- **How does it fit into the current and future system of circular materials?** We need to consider compatibilities with the current and future recycling infrastructure and practices to make sure that when new materials are introduced there are systems in place to keep these materials in circulation or recycled multiple times.

The types of new materials (including textiles) we should consider include:

- **Bio-based plastics:** The source material comes from biomass, decoupling the production of plastics from fossil fuels and supporting the transition to a circular economy. Provided the biomass is produced sustainably and the energy input (i.e. fossil-fuel input) involved in growing, fertilising, harvesting and processing the biomass is not greater than simply making plastic from crude oil, these may have reduced greenhouse gas emissions. Use of bio-based plastics is predicted to increase from around 4 million tonnes produced in 2016 to 6 million tonnes in 2021.[393] Bioplastics currently comprise only 1% of total plastics production, so there is plenty of scope to increase the use of these

[390] As an example, when asked what in her life time had made the biggest impact on her, Riro Spackman (1916-2009) replied that it had been the invention of plastic.
[391] Alaerts et al., "Impact of Bio-Based Plastics on Current Recycling of Plastics," *Sustainability* 10, no. 5 (2018)
[392] Trager, "Concerns Raised over 'Regrettable' Bpa Substitutions", *Chemistry World*, 22 August 2019
[393] European Bioplastics, "Bio-Based Building Blocks and Polymers: Global Capacities and Trends 2016–2021", 2017

plastics. As discussed in Section 1.2.4, 'bio-based plastics' and 'biodegradable plastics' mean different things and plastics can be either or both – the first relates to what it is made from and the other to how it breaks down.

- **Biodegradable and compostable plastics:** These allow for simple disposal of plastic items at their end-of-life with the resulting materials being put to use as compost or degrading in the environment. Compostable plastics require new processing methods to fully meet market needs and are typically more expensive than fossil fuel- based plastics. More companies have been using compostable plastics in recent years, but studies in Aotearoa New Zealand have highlighted a lack of infrastructure to manage compostable plastic waste.[394] Considerable research is being undertaken internationally and in Aotearoa New Zealand to solve current issues with compostable plastics. The disposal of compostable plastics is complicated by the fact that some materials, notably most forms of PLA, need industrial high temperature composting facilities to fully degrade.[395]
- **Next-generation plastics:** Less research is being done on wholly new materials to make plastics because of the challenges of manufacturing at sufficient scale and low enough price to replace existing plastics.
- **Non-plastic alternatives:** A whole range of new materials is being developed from a wide variety of sources to replace plastics. Many of these are developed from renewable sources.

As well as new materials, new manufacturing processes designed to complement their properties are being designed. For example, new innovations include additive manufacturing (e.g. 3D and 4D printing). Materials innovations are occurring worldwide in industry and academia, and through collaborations between the two, but uptake at larger scale is limited, particularly locally (see Case Study 3.7.1). In Aotearoa New Zealand, there are several research institutes that are able to collaborate with businesses to develop customisable solutions and progress our transition to a more bio-based circular economy for plastic use. For example, Scion has collaborated with Zespri to develop the Biospife (see Case Study 3.7.2),[396] with EPL to develop a biodegradable wine net clip,[397] and with Imagin Plastics to develop a 3D printer filament.[398]

There is great potential for Aotearoa New Zealand's research institutes and universities to carve out a niche for our plastics manufacturing industry in the bio-based and biodegradable plastics markets and to connect with international research efforts for new materials (e.g. the NSF Centre for Sustainable Polymers[399]). Ensuring we keep up with international best practice is a particularly important consideration for our export industry. As a country that relies heavily on our export industry, it is imperative that Aotearoa New Zealand factors in the potential implications of international regulations relating to circular economy and sustainable packaging initiatives. An example of where innovation allowed a large exporter to meet the sustainability demands of the countries they export to is the biospife developed by Zespri (see Case Study 3.7.2).

In Table 22 we present opportunities and limitations of new alternatives to replace traditional plastics. We discuss how these may or may not play a role in Aotearoa New Zealand's transition to a circular economy.

[394] Beyond the Bin, "A Review of the Availability of New Zealand Compost Facilities to Process Compostable Coffee Cupes and Food Packaging", 2017
[395] Parliamentary Commissioner for the Environment, "Biodegradable and Compostable Plastics in the Environment", 2018
[396] Scion, "Annual Report," (2017)
[397] More information available at: http://www.plastics.org.nz/news-events/new-zealand-plastics-industry-design-awards/2019-design-awards-finalists/biodegradable-wine-net-clip
[398] Scion, "Nz Made, Wood Fill 3d Printing Filament Hits the 'Shelves'", *Scion Connections*, June 2018
[399] More information available at: http://csp.umn.edu/

Table 22 Material innovations and their potential application in Aotearoa New Zealand

Material	Strengths	Limitations	Possible solutions	Examples/ ongoing research
Bio-PET (#1) A partially bio-based plastic	Fully recyclable Identical to fossil-PET (#1) so can be processed with it Existing infrastructure is sufficient	Currently relies on some fossil-based feedstock and doesn't reduce environmental impacts compared to standard PET (#1) (see Case Study 4.5.1) Non-biodegradable if leaked into environment	R&D to make 100% bio-sourced – widely sought	Coca-Cola planning to make 100% bio-based PET (#1) bottles by 2020[400]
Bio-HDPE (#2) A bio-based plastic	Fully recyclable and can be reprocessed with standard HDPE (#2), so existing infrastructure is sufficient Ethylene, the raw material, is readily bio-sourced	Non-biodegradable if leaked into environment Cost is currently a barrier for companies	Develop onshore sourcing/ production Incentives for brands to use bio-based plastics	Ecostore use a bio-HDPE (#2) product (see Case Study 2.5.2)
Bio-sourced polyester A bio-based plastic	Recyclable (in practice)	Lacking system to recycle clothing Most clothing imported, not manufactured in NZ	Retailers to demand bio-based options	

[400] "Coca-Cola's 100% Plant-Based Bottle",

Material	Strengths	Limitations	Possible solutions	Examples/ ongoing research
PLA A bio-based, compostable plastic	Circular potential because the compost produced can be used to grow plants to generate more PLA Physical properties similar to PET (#1) so could be a substitute for these applications	Severe incompatibility with PET (#1) recycling, but easily mistaken for PET (#1) – high potential to contaminate[401] Lack of technology in current sorting systems to recognise and remove PLA from PET (#1) stream Lack of available commercial composting infrastructure Currently no local manufacture In low oxygen environments, particularly landfill, degradation can produce methane Not currently mechanically recyclable in NZ Still persistent if leaked into environment	Sorting technology Build commercial composting facilities Build onshore manufacturing facility Use modern landfill or capture methane from degradation	NZ companies providing PLA packaging, e.g. Earthpac, Ecoware, Grounded Packaging[402] Research to further develop underway at Otago[403] and Scion[404]

[401] Alaerts et al., "Impact of Bio-Based Plastics on Current Recycling of Plastics,"
[402] More information available at: https://www.ecoware.co.nz/; https://groundedpackaging.co/; https://earthpac.co.nz
[403] Scientists at Otago University are developing new catalysts to make PLA and other lactide based plastics cheaper and more efficient.
[404] Scion are developing new ways of processing PLA so it can be used in a wider variety of applications, the incorporation of natural materials as strengthening in composite plastics and development of PHA sourced from bacterial fermentation of waste products.

Material	Strengths	Limitations	Possible solutions	Examples/ ongoing research
PHAs, including PHB A bio-based compostable or biodegradable plastic (depending on conditions) produced by microbial fermentation of a wide variety of feedstocks	Varied potential applications and properties (e.g. soft and rigid plastics) Circular potential because the compost produced can undergo microbial fermentation to produce more PHA Microbially degraded (not compost) can be degraded in the environment to water and CO_2 – hence circular as plants can reuse Potential textile applications PHB properties similar to PP (#5) so could replace this PBAT evidence as fully biodegradable[405] PHB can be made from methane gas feedstock so additional climate change benefits – can use gas produced from landfills etc. Kaneka's PHBH 90% marine biodegradable in 6 months[406] Manufacture doesn't require large, centralised facilities – suits onshore manufacture	Processing issues due to variability in feedstock Can be made from forestry waste so good economic opportunity for Aotearoa NZ If compostable plastics go into low oxygen environments, particularly into landfill, their degradation can produce methane. Not recyclable with current mechanical recycling infrastructure Cost prohibitive for brands	Proper testing facilities so only certified materials used locally (e.g. Scion)[407] Use modern landfill to capture methane Use of waste streams as biomass to bring price down	Available now Bio-on develops numerous applications, including a cosmetic product line with Unilever[408] Danimer is developing a variety of applications, including snack bag material for PepsiCo[409] Research to improve underway at Scion and research to manufacture various types of PHA Methane-derived PHB developed by Mango Materials – currently produce textiles and caps in pilot plant[410]

[405] Zumstein et al., "Biodegradation of Synthetic Polymers in Soils: Tracking Carbon into Co2 and Microbial Biomass," *Science Advances* 4, no. 7 (2018)
[406] Barrett, "Kaneka Wins Japan Bioindustry Award 2019 for Seawater Biodegradable Bioplastics", *Bioplastics News*, 7 August 2019
[407] In New Zealand Scion have developed an internationally certified facility to test compostability claims to a range of standards http://www.scionresearch.com/about-us/news-and-events/news/2019/compostability-facility-gains-accreditation
[408] More information available at: http://www.bio-on.it/
[409] More information available at: https://danimerscientific.com/
[410] More information available at: http://mangomaterials.com/

Material	Strengths	Limitations	Possible solutions	Examples/ ongoing research
Seaweed-based packaging A non-plastic alternative	Can replace multi-layered plastic sachets Compostable	Competiton for food source May contaminate plastic recycling streams Possible biosecurity issues	Use for niche applications	Evoware[411]
Fungal protein-based materials A non-plastic alternative	Made from natural polymeric materials Can replace EPS, which is a problematic plastic	Possible allergenics Possible biosecurity issues when imported	Onshore manufacture	NZ Biopolymer Network partnership with Meadow Mushrooms to make mushroom packaging[412] The US company Ecovative Design grows the structural component of fungi, mycelia, to replace plastics used in packaging[413] The SCOBY (symbiotic culture of bacteria and yeast bound in cellulose) that ferments tea into kombucha has been used a textile by US company Kombucha Couture[414]
Cork A non-plastic alternative	Bio-based and biodegradable Anti-bacterial, water-resistant and strong	Scale		Lush has developed carbon-positive cork packaging to replace plastic[415]
Vitrimers A next-generation plastic	Recyclable/ remoldable version of thermosets Potential to replace lots of unrecyclable plastics that are discarded, especially thermosetting resins that are used in composite materials	Still in research and pilot phase	Further R&D Scale-up facilities	US company Mallinda developing new vitrimer composites[416]

[411] More information available at: https://www.newplasticseconomy.org/innovation-prize/winners/evoware
[412] Flaws, "Mushroom Company to Make Its Own Packaging - from Mushrooms ", *Stuff*, 13 June 2019
[413] Fox, "Just 10% of U.S. Plastic Gets Recycled. A New Kind of Plastic Could Change That", *Science*, 22 April 2019
[414] More information available at: http://www.kombuchacouture.com/
[415] Lush, "First-Ever 'Carbon-Positive' Packaging Made from Cork", press release, 1 August 2019, https://www.springwise.com/innovation/beauty/carbon-positive-packaging-lush-cosmetics
[416] More information available at: https://www.mallinda.com/

Material	Strengths	Limitations	Possible solutions	Examples/ ongoing research
Recyclable thermosets A next-generation plastic	Drop-in solution to standard epoxy resins	Infrastructure to recycle	Develop this onshore	Connora makes these[417]
Starch-derived materials A bio-based, compostable alternative to plastic	Compost produced can be used to grow plants to generate more starch to make their processing circular	Material properties e.g. poor water resistance limits use	Niche applications	Research at Scion Earthpac manufacture certified compostable starch-based products in NZ[418]
Cellulose-based materials (e.g. bamboo, cellophane) A bio-based, compostable alternative to plastic	Made from natural materials	Material properties No current manufacture	Can purchase from international producers, e.g. Celluforce,[419] Oji Japan, Stora Enso,[420] Weidmann Fiber Technology[421] Repurposing of current fibre mills (e.g. Oji in Japan)	Researchers at the University of Canterbury developing all-cellulose composites[422] Transparent wood cellulose: a fibrous cellulose (HefCel); and a plastic type cellulose (MMCC) developed but not yet on market[423] Used for textiles substituting cotton and polyesters; coatings for paper and other product substitutes

[417] More information available at: http://connoracomposites.com/
[418] More information available at: https://earthpac.co.nz/
[419] More information available at: https://www.celluforce.com/
[420] More information available at: https://www.storaenso.com/
[421] More information available at: https://weidmannfibertechnology.com/
[422] Huber et al., "Solvent Infusion Processing of All-Cellulose Composite Materials," *Carbohydrate Polymers* 90, no. 1 (2012)
[423] More information available at: https://www.newplasticseconomy.org/innovation-prize/winners/vtt-technical-research-centre-of-finland

Material	Strengths	Limitations	Possible solutions	Examples/ ongoing research
Animal waste protein-based material A non-plastic alternative	Made from natural polymeric materials	In general these natural materials do not have the full range of desirable properties as plastics, particularly water and oxygen resistance, unless chemical additives are used, which may give the materials the same undesirable properties as plastic such as environmental toxicity	Niche applications Further R&D	Researchers from the University of Waikato have produced a plastic from meat rendering waste called Novastein that can be used as a biodegradable replacement for plastic in rigid items that do not require particular strength, such as seed trays and plant pots[424] Researchers at the University of Canterbury and AgResearch developing these[425]
Milk protein-based materials A non-plastic alternative	Made from natural polymeric materials	Application likely to be limited to specific niche applications where their properties are sufficiently desirable		Based on old methods but can be further developed[426]
Novel natural polymers A non-plastic alternative	Made from natural polymeric materials	Application likely to be limited to specific niche applications where their properties are sufficiently desirable		NZ company Humblebee is working on developing a material produced by a species of bee to waterproof their nests. The material is resistant to temperature, acids and bases, and solvents but, as mimicking a natural material, is likely to be biodegradable. Work is ongoing to develop a manufacturing method[427]

[424] More information available at: https://sci.waikato.ac.nz/research/projects-and-case-studies/biodegradable-plastic-from-animal-protein-waste
[425] More information available at: https://www.canterbury.ac.nz/engineering/schools/mechanical/research/naturalfibres/
[426] More information available at: https://whanganuiregionalmuseum.wordpress.com/tag/the-new-zealand-casein-company/
[427] More information available at: https://www.humblebee.co.nz/technology

Material	Strengths	Limitations	Possible solutions	Examples/ ongoing research
New composites A next-generation plastic	Wide-ranging potential applications, e.g. chair seats, automotive parts, shoe heels, garden pieces, lamps, 3D printing materials Can couple new materials with range of plastics	Recyclability	Design for circular principles (e.g. for disassembly and repair) to keep in use	Research underway looking at using harakeke in with pre-consumer recycled PP (#5) to make a composite[428] Scion has developed Woodforce, natural wood fibres replacing glass fibre in plastic composites[429]
Bio-adhesives A non-plastic alternative	Renewable resources Free of petrochemicals and formaldehyde Water-based, non-toxic and compatible with existing adhesive and wood panel manufacturing equipment	Needs development for plastics applications	Further R&D	Scion has developed Ligate, a bioadhesive for wood panels[430]

[428] Stoof et al., "Sustainable Composite Fused Deposition Modelling Filament Using Recycled Pre-Consumer Polypropylene," *Composites Part B: Engineering* 135 (2018)
[429] More information available at: http://www.woodforce.com/
[430] More information available at: https://www.scionresearch.com/science/bioproducts-for-sustainable-industries/bioadhesives

3.7.1 Case study: What's stopping the uptake of new materials?

New material innovations start with research and development. Through an iterative process, researchers (often alongside their industry partners) make and test materials until the new material has all of the desired properties for that application. This can take years. Next, the new material needs to be taken out of the lab and into the real world. This presents a whole new series of challenges.

Critical success factors to drive local development and uptake of sustainable new materials as part of a circular economy include:

- **Regulation that incentivises industry to use more sustainable materials**. Product bans or other incentives can help drive uptake of new materials that have been specifically designed to replace problematic materials or products, or address international standards and non-tarrif barriers.
- **Connection across the value chain**. Researchers, brand owners and manufacturers all need to be well connected to identify material needs, capitalise on innovation opportunities, and ensure the application need is met. A research and innovation system that supports risk takers and bold ideas is fundamental to achieving this.
- **Supply of appropriate feedstock for scale-up**. There are huge opportunities within Aotearoa New Zealand to use biomass to make new materials, particularly using the waste from one process as the raw material for another. Businesses need to be connected with other businesses and researchers to identify these opportunities.
- **Scale-up facilities** to trial and demonstrate new materials beyond proof-of-concept when local manufacturers are unwilling to take risks with their equipment for new materials. These facilities are critical for developing the markets needed for scale-up and are currently lacking, particularly for the equipment modifications needed to process biomass into new products.
- **Manufacturing infrastructure**, which may require modification of existing equipment or development of new facilities, depending on the material. Aotearoa New Zealand has the potential to meet growing global demands for bio-based materials but requires onshore manufacturing processes to do so.
- **Development of product prototypes**, to demonstrate performance for the application and allow for market testing. For new materials, providing evidence of circularity at this stage is important.
- **Systems to support circularity** of new products. When new materials are coming onto the market their whole life cycle, including end-of-life options, needs to be considered and infrastructure and systems developed to keep the resource in circulation.

Actions to support uptake of bio-based materials will be covered further in Scion's Roadmap for New Zealand's New Plastics Economy.

3.7.2 Case study: Staying at the leading edge of global sustainability trends

Zespri International Limited is the world's largest marketer of kiwifruit. It is owned by Aotearoa New Zealand kiwifruit growers and sells premium kiwifruit into more than 50 countries, managing around 30% of the global volume. Kiwifruit makes up just a fraction of globally-traded fruit so making it easy for consumers to cut, scoop and eat the fruit is a key part of growing demand for kiwifruit around the world. To help achieve this, Zespri released a spife, a spoon-knife utensil, made out of polystyrene (#6) plastic, in the 1990s.

Figure 40 The biospife developed by Zepsri

Around 2010, the debate about 'food miles' prompted Zespri to assess the carbon footprint of transporting kiwifruit to the European market. At the same time, European customers, initially those purchasing organically-grown kiwifruit, were expressing concern about the plastic in the spife and the inability to dispose of it in a more environmentally-friendly manner.

Zespri recognised that changing consumer expectations, along with rising concern about climate change and non-renewable resource use, were likely to lead to increased regulations in the global market. Analysis showed the plastic spife contributed to ~3% of Zespri's total carbon footprint. In addition, the industry produced waste biomass (low-grade fruit) each season. There was clearly an opportunity to improve the sustainability of the business and build added brand value.

Zespri partnered with Scion along with Alto Packaging Limited to develop and manufacture spifes made from bioplastics and residual kiwifruit waste. Its design was guided by industrial composting standards and it is considered one of the first successful initiatives showcasing product development aligned to the principles of the circular economy.

While there are ongoing challenges with the availability of industrially composting facilities, a reusable and industrially-compostable spife continues to meet with favourable consumer sentiment. As investment in more advanced waste infrastructure expands offshore, Zespri is well placed to capitalise on this.

Zespri has some insights for other exporters on successfully navigating future regulatory trends to guide business decisions and innovate to meet these needs. These include:

- Invest in understanding future trends
- Measure the environmental impacts of your business and your products
- Understand consumer sentiment in your markets
- Develop long-term partnerships to support innovation
- Collaborate with scientists, technical experts and companies in the value chain
- Be patient – it takes time to bring concepts to commercial reality
- Show leadership – while the solution may not be perfect, each step shifts a complex system towards the goal (in case this, a circular economy solution)
- Perservere with blockages in the value chain (see Case Study 3.7.1)

Further complexity is likely to come from the potential divergence of countries that import Aotearoa New Zealand products into two camps – those that have strict regulations on imported plastics and packaging and those that do not. Collaboration between companies to develop solutions to meet the needs of various jurisdictions may prove crucial for exporters to stay ahead of non-tariff barriers and meet consumer needs.

3.8 Dispose

While the ultimate goal is to achieve zero plastic waste, realistically, for the foreseeable future there will be an amount of plastic waste that needs to be disposed of. To be an effective tool in helping to combat climate change, waste minimisation must focus on reducing the creation of waste as a primary objective. Once waste is produced, we need to consider the carbon footprint of the processes involved in managing that waste, including assessing the consumption and impacts of burning hydrocarbons (long cycle carbon impact) during the collection, separation, recovery and recycling processes. We can then benchmark the benefits (or otherwise) of these processes against the carbon footprint of alternative processes such as landfilling, which will include generation and potential beneficial reuse of methane produced by modern landfills (see Case Study 3.8.1).

Figure 41 Example of waste headed for disposal

Aotearoa New Zealand currently relies on landfill to dispose of most waste plastic (the exception being some medical and airline waste that may include plastics). Other jurisdictions, including those in Europe and the US, also use controlled incineration.

In Aotearoa New Zealand's context there are a number of limiting factors that mean that controlled incineration is not an ideal disposal solution for our plastic waste. These include:

- An incineration plant would require a certain amount of waste to be economic – this could have the perverse outcome of incentivising waste production (as argued in The Conversation[431])
- Upfront costs of developing a single waste-to-energy incineration plant being prohibitive (estimated to be around $1 billion) – therefore, at a maximum only one plant may be feasible for the whole country
- Transporting waste throughout the country to one plant would have a high emissions footprint. Using a rail network to achieve this is unlikely to be feasible given the logistics of getting waste to the part of the network where it could be onboarded (e.g. all Auckland waste would need to be loaded at Penrose in the current scenario)
- Technology and infrastructure for smaller plants, which may be better suited to our local context, are not available at scale
- Landfill would still be required for residual waste that remains after controlled incineration
- Depending on application, may be prohibited under the National Environmental Standard for Air Quality.[432]

Instead, it may be more appropriate for Aotearoa New Zealand to continue to rely on modern landfill facilities that can only be developed and operated in accordance with strict consent conditions and quality assurance measures (further details in Appendix 4).

AN INCINERATION PLANT WOULD REQUIRE A CERTAIN AMOUNT OF WASTE TO BE ECONOMIC – THIS COULD HAVE THE PERVERSE OUTCOME OF INCENTIVISING WASTE PRODUCTION

[431] Farrelly, "Why Municipal Waste-to-Energy Incineration Is Not the Answer to Nz's Plastic Waste Crisis", *The Conversation*, 13 November 2019
[432] Ministry for the Environment, "2011 Users' Guide to the Revised National Environmental Standards for Air Quality", 2014

3.8.1 Case study: Modern landfill – a waste-to-energy innovation

In 2016, Aucklanders sent 1.6 million tonnes of waste to landfill for disposal. Around 14% came from household kerbside collections, and 86% from commercial and other activities. That's over one tonne of rubbish for every Aucklander.[433] The Redvale Landfill and Energy Park, north of Auckland, is an example of a modern landfill, engineered to recover energy from the waste that is securely disposed of to land. Developed, owned and operated by Waste Management NZ Ltd, the landfill receives approximately 50% of Auckland's residual waste for disposal. By weight, plastics accounts for approximately 14% of this waste stream.

Figure 42 Redvale Landfill and Energy Park. Source: Redvale Landfill and Energy Park

Unlike the historical dumps operated prior to the introduction of the Resource Management Act 1991, a modern landfill such as Redvale provides an environmentally secure point of disposal with sophisticated engineering that prevents leakage of landfilled materials into the environment. An engineered liner and leachate management system is developed prior to any waste placement which ensures the leachate is extracted and treated by an approved process. As methane is produced by the decomposing organic refuse and potentially biodegradable plastics, a landfill gas management system is progressively installed within the waste to capture and extract the landfill gas, which is then used as a source of renewable energy.

At the Redvale facility the landfill gas, which is approximately 50% methane, is used to generate electricity and provide a source of heating and carbon dioxide to a neighbouring Aubergine greenhouse complex. Currently Waste Management extracts approximately 36 million cubic metres of methane out of the landfill per annum and turns it into clean, green energy, rather than letting it contribute to climate change. Redvale landfill's current energy generation has the capacity to power 14,000 homes on the local grid making it Auckland's largest generator of renewable energy. It is estimated that the landfill could power up to 18,000 homes by 2025. Once closed, Redvale Energy Park will continue to generate renewable energy, albeit it at a declining rate, over the following 25 to 30 years.

CURRENTLY, REDVALE LANDFILL'S ENERGY GENERATION HAS THE CAPACITY TO POWER 14,000 HOMES ON THE LOCAL GRID

Though we aspire to achieve zero waste for plastics in the future, we need a disposal solution that can be used now. It is economic to establish infrastructure for modern landfills around the country (to reduce emissions related to transporting waste), and these facilities can be engineered to ensure low environmental impacts coupled with gas capture and energy generation. The best practice demonstrated by modern landfills such as Redvale needs to become standard practice across landfills in Aotearoa New Zealand in order to reduce the environmental impacts associated with disposing of plastic waste, including remediating legacy dumps at risk of damage (see Case Study 4.20.2).

[433] Auckland Council, "Auckland Waste Management and Minimisation Plan 2018 ", 2018

3.9 Summary and recommendations

There are multiple different new ideas and innovations that will all play an important role in rethinking plastics in Aotearoa New Zealand. There is no single solution, and creating a more sustainable future will require an environment that supports ongoing innovation and scaling up of good ideas. It is important that we don't rush into implementing solutions without first testing their safety and effectiveness. New ideas or systems can be first implemented in communities or regions, assessed, tweaked, and scaled-up if successful. The safety of new materials or products made from recycled content also need to be stringently tested before being implemented to ensure that we are not creating further environmental risks with new products. It is important to be wary of unintended consequences. Actions that are necessary to support new ideas and innovations are addressed within recommendations 2, 4 and 5.

Key considerations for implementing these recommendations:

Labelling

- Material identification should be consistent with international standards and universally understood. This could be achieved by adopting or aligning to international standards:
  - For resin identification (e.g. ASTM D7611/ D7611M; China GB/T 16288-2008; EU 97/129/EC) and compostable packaging (e.g. home: AS 5810; AS 5810/ NF T 51-800; commercial: AS 4726; EN 13432; ASTM D 6400 or 6868).
  - For composting (drawing on WasteMINZ guide to compostable packaging).[434]
- The label's material and how it is affixed may impact on the recyclability of a product – recyclers could help inform material choice for a new labelling system or this could follow best-practice demonstrated by Denmark's regulation around labelling materials (see Case Study 3.6.5).

Infrastructure

- Waste incineration could lead to over-capitalisation and perverse incentives to increase waste.
- As there is enough onshore capacity for PET (#1) recycling, the focus should shift to HDPE (#2) and PP (#5).
- Material flow analyses to determine infrastructure requirements for onshore reprocessing should consider the different applications needed for recycled content (e.g. food grade vs detergent grade for HDPE (#2)) and the processes that may help maximise use for these applications (e.g. source separation through CDS or PSS, or chemical recycling to decontaminate).
- If brands continue to use compostable plastics, commercial composting infrastructure and systems to support collection would be needed.

Innovation

- Callaghan Innovation could help facilitate connections between business and researchers to develop innovative solutions.
- The UK plastics research and innovation fund to increase reuse and recycling could be modelled from.[435]
- Local innovators could be encouraged to enter international competitions such as the New Plastics Economy Innovation Prize[436] and the National Geographic Innovation Challenge: Ocean Plastic.[437]

[434] WasteMINZ Organic Materials Sector Group, "Guides to Terminology for Compostable; Biodegradable, and Oxo-Degradable Products" https://www.wasteminz.org.nz/pubs/guides-to-compostable-packaging-terminology/
[435] More information available at: https://www.ukri.org/research/themes-and-programmes/tackling-the-plastics-problem/
[436] More information available at: https://www.newplasticseconomy.org/projects/innovation-prize
[437] More information available at: https://www.nationalgeographic.org/funding-opportunities/innovation-challenges/plastic/

4. Plastics and the environment – life cycle assessment and beyond

ME MĀTAU KI TE WHETŪ
I MUA I TE KŌKIRI O TE HAERE[438]

In this chapter, we focus on the environmental impacts of plastic. Through a series of case studies we demonstrate the importance of thinking about the environmental impacts of a product's whole life cycle – not just its disposal. We then summarise the growing body of evidence around the impacts of plastic in the environment and what this means for Aotearoa New Zealand.

[438] Before you set forth on a journey, be sure you know the stars

4.1 Rethinking plastics: focusing on the environment

The thinking around how plastic impacts the environment often focuses on plastic that has leaked into our oceans due to mismanagement at its end-of-life. Other catastrophic events, such as the recent high-profile failure of a landfill on the West Coast, also bring the issue of plastic in the environment to the fore.[439] There is a growing body of evidence that details the impacts of plastic that has leaked into the environment, which we summarise later in this chapter.

While there is no denying that plastic pollution is problematic, it is not the only consideration that we should take into account when deciding whether use of plastic product is sustainable. Plastics do not only have an impact on the environment at end-of-life. Acquiring the raw material to produce virgin resin, manufacturing that resin into a product, distributing the product through its supply chain to end-market, using the product, and disposing of or recovering the materials all require resources and generate outputs that have environmental impacts (see Figure 43). Other materials generate environmental impacts throughout the whole life cycle as well. The material that is the least environmentally damaging will depend on context and application – evaluating differences in life cycle environmental impacts in combination with the risks of environmental leakage on ecosystems and the potential health implications of different materials can help guide these decisions.

Ensuring that the future production, consumption and disposal of plastics is sustainable aligns to te ao Māori (introduced in Section 1.3.1), because it recognises that earth's resources are finite and that the appropriate use and management of these resources is fundamental to the wellbeing of people, communities and our natural environment. Sustainable use of resources has received growing attention more recently in the Western world view and research community.[440] Other significant learnings from mātauranga Māori that can help shape our response to the environmental impacts of plastic include taking a holistic, systems view of the impact of plastic and embracing the strength of local knowledge and action to observe and remediate environments.

The importance of considering the full life cycle of a product was articulated in Plastics and Health: The Hidden Costs of a Plastic Planet by the Center for International Environmental Law (CIEL).

> "The narrow approaches to assessing and addressing plastic impacts to date are inadequate and inappropriate. Understanding and responding to plastic risks, and making informed decisions in the face of those risks, demands a full life cycle approach to assessing the full scope of the impacts of plastic on human health. This includes to ensure that we are not creating yet more and increasingly complex environmental problems in attempts to address this one."[441]

[439] More information available at: https://www.westlanddc.govt.nz/fox-landfill-clean
[440] Raworth, *Doughnut Economics: Seven Ways to Think Like a 21st Century Economist*.; Rockstrom et al., "Planetary Boundaries: Exploring the Safe Operating Space for Humanity," *Ecology and Society* 14, no. 2 (2009); Biermann, "Planetary Boundaries and Earth System Governance: Exploring the Links," *Ecological Economics* 81 (2012)
[441] Center for International Environmental Law, "Plastic & Climate: The Hidden Costs of a Plastic Planet ", 2019

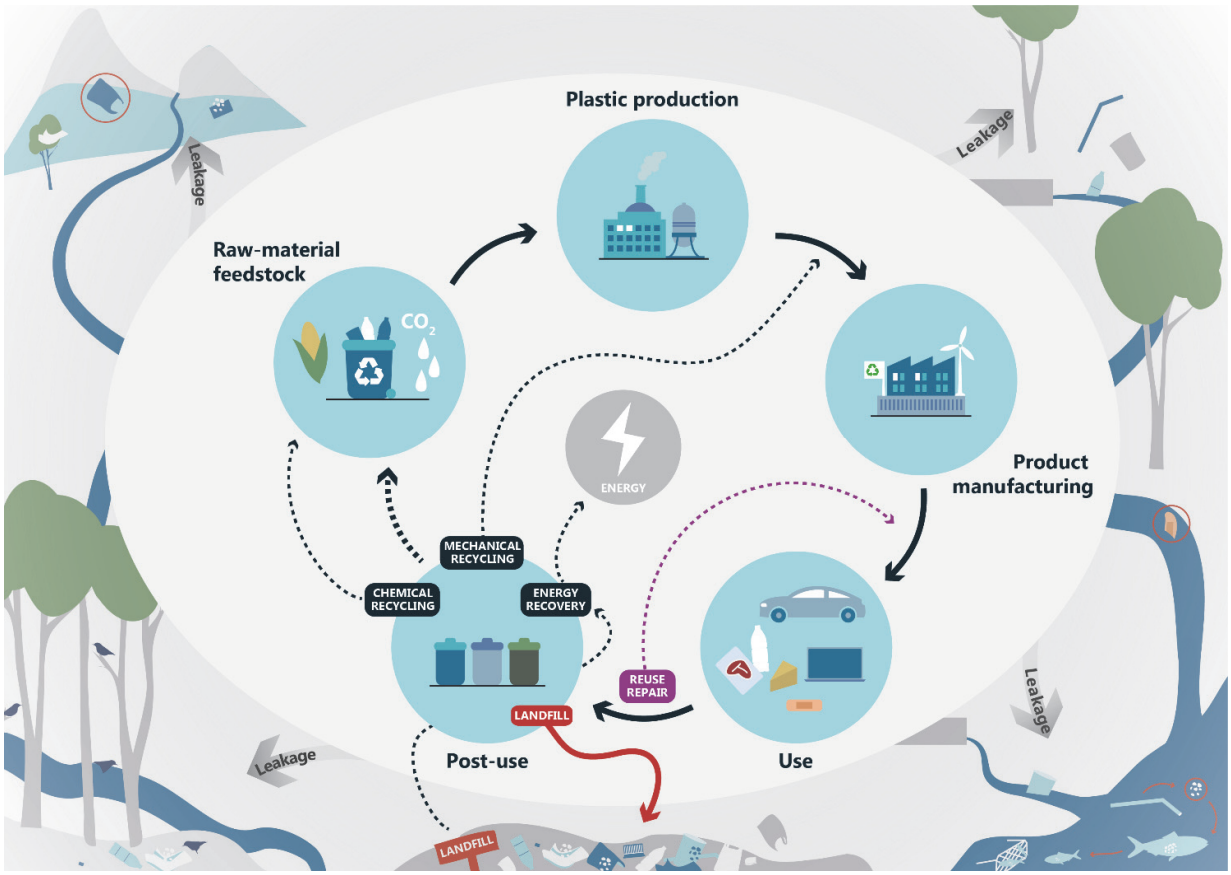

Figure 43 The life cycle of plastic from resource extraction of raw-material feedstock to end-of-life disposal and possible re-entry into the use cycle. Leakage into the environment is a potential end-of-life scenario. Adapted from Plastics Europe

4.2 Reducing emissions from plastics

Plastics contribute to climate change across the whole life cycle – from the extraction of fossil fuels as feedstock for plastics through to the climate change impacts of the end-of-life option for plastic waste. A comprehensive report on the topic, led by CIEL, highlights how plastics produce greenhouse gas emissions across the life cycle.[442]

In brief, emissions occur from:

- **Extraction and transport:** leakage, fuel combustion, energy consumed during drilling for oil or gas, and land disturbance when forests or fields are cleared for drilling and pipelines.
- **Refining and manufacture:** the cracking of alkanes into olefins, the polymerisation and plasticisation of olefins into plastic resins, and other chemical refining processes.
- **Waste management:** incineration in the open (extremely high), recycling (moderate – and advantageous because it displaces new virgin plastic) and landfilling (least – but could increase with more biodegradable plastic releasing methane).
- **Plastic in the environment:** early reports suggest that plastic on the ocean surface and on coastlines, riverbanks and landscapes may release methane and other greenhouse gases,[443] and that microplastics in the oceans may interfere with the ocean's capacity to absorb and sequester carbon dioxide.[444] Further research is needed to confirm these findings.

At the product level, plastics can contribute to reducing our climate change impacts because plastic is lighter than most alternative materials it replaces. An example is the use of plastic rather than metal in aeroplanes, which makes the plane lighter and therefore reduces fuel consumption. Another example is through net reduction in impact due to food preservation that may be lost with alternatives or the removal of packaging altogether. It is important to consider the climate change impacts of alternatives that could replace plastic products to ensure that rethinking plastics does not lead to a net increase in climate change impacts.[445]

However, while we can look at the climate change impact of individual products, it is actually the overall scale of plastic production, use and consumption that threatens our ability to meet global climate targets.[446] Even conservative estimates say the volume of consumed plastics – which has doubled since the turn of this century – will quadruple by 2050 if no changes are made.[447] As described in Section 1.1, with the projected growth in use, plastic is estimated to be responsible for up to 15% of the total 'carbon budget' by 2050.

Evidence suggests that the combination of using less plastic overall (e.g. through replacement with other materials or reuse systems), aggressive application of renewable energy, recycling and replacing fossil-fuel feedstock with biomass has the potential to reduce emissions from plastics and achieve an absolute reduction from the current level. [448]

[442] Center for International Environmental Law, "Plastic & Climate: The Hidden Costs of a Plastic Planet ", 2019
[443] Royer et al., "Production of Methane and Ethylene from Plastic in the Environment," *Plos One* 13, no. 8 (2018); Ward et al., "Sunlight Converts Polystyrene to Carbon Dioxide and Dissolved Organic Carbon," *Environmental Science & Technology Letters* (2019)
[444] Besseling et al., "Nanoplastic Affects Growth of S. Obliquus and Reproduction of D. Magna," *Environmental Science & Technology* 48, no. 20 (2014); Yokota et al., "Finding the Missing Piece of the Aquatic Plastic Pollution Puzzle: Interaction between Primary Producers and Microplastics," *Limnology and Oceanography Letters* 2, no. 4 (2017); Prata et al., "Effects of Microplastics on Microalgae Populations: A Critical Review," *Science of the Total Environment* 665 (2019)
[445] Plastics Europe, "The Impact of Plastics on Life Cycle Energy Consumption and Greenhouse Gas Emissions in Europe (Summary Report)," (2010)
[446] Center for International Environmental Law, "Plastic & Climate: The Hidden Costs of a Plastic Planet ", 2019
[447] World Economic Forum, "The New Plastics Economy: Rethinking the Future of Plastics", 2016
[448] Zheng et al., "Strategies to Reduce the Global Carbon Footprint of Plastics," *Nature Climate Change* 9, no. 5 (2019)

4.3 The place for life cycle assessment in rethinking plastics

Ideally, individual consumer choices, product development and design choices, and policy decisions would all be informed by robust evidence about what is sustainable and best for the environment. That evidence needs to consider a product's impacts across the full life cycle, including if it leaks into the environment, and not just its end-of-life options. Pragmatically, the information that could help to inform these choices is not widely available or accessible – for example, it won't be immediately clear to a person making a decision at the supermarket which product has a lower environmental impact. This often forces people to make their decision based solely on end-of-life options (i.e. it is recyclable or not) or preconceived ideas about what is better (e.g. assuming cardboard is better than plastic, without evidence). Life cycle assessment (LCA)[449] can be used to inform choices by evaluating and comparing the full life cycle environmental impact of different options, including different end-of-life options. LCA studies highlight any trade-offs that arise when considering alternatives, and through use of a 'functional unit' as the basis for the analysis, enable fair comparisons. It is important to emphasise that there are often no clearly preferred outcomes in comparisons between products made from plastics versus other materials. For example, Product A may have a lower climate change impact but cause more damage to rivers than Product B, so the decision will partly rest on value judgements on the various types of environmental impacts, alongside economics. The preferred product or system will also depend upon factors such as the geographical context, user behaviour, and structure of local waste management systems.

LIFE CYCLE ASSESSMENT (LCA) CAN BE USED TO INFORM CHOICES BY EVALUATING AND COMPARING THE FULL LIFE CYCLE ENVIRONMENTAL IMPACT OF DIFFERENT OPTIONS, INCLUDING DIFFERENT END-OF-LIFE OPTIONS

The current limitation of relying solely on LCA to inform these choices is that it doesn't account for the environmental impacts caused by plastic leaking into the environment as litter. To date, some studies have developed separate indicators for litter (see Case Study 4.4.1) but these are not part of the LCA methodology itself. There are efforts underway to allow integration of the potential environmental impacts of marine litter into LCA results. The Marine Impacts in LCA project is working on a framework paper to illustrate the different impact pathways associated with marine litter, and this is due to be published in December 2019. But the final framework for incorporating marine litter into LCA studies is not expected until 2025.[450]

There are many opportunities to use LCA to quantify the environmental impacts of a product or system and support evidence-informed decisions when rethinking plastics. Here we illustrate the relevance of LCA through a series of key questions:

- Are reusable products always better than single-use alternatives?
- Should we switch to bio-based plastics?
- Is recycled plastic actually better for the environment?
- Should we ban plastic packaging altogether?
- Should we use an alternative material to plastic?
- Should we restrict our use of plastic to certain types?
- What end-of-life options for plastic are best for Aotearoa New Zealand?

[449] Life cycle assessment (LCA) is a systematic method to evaluate the different environmental impacts of a product through its entire lifespan – from raw material production through manufacture, use and on to disposal or reuse. There are international standards and guidance for the methodology, as well as local workstreams in Aotearoa New Zealand (see Appendix 5).
[450] More information available at: http://marilca.org/

4.4 Are reusable products always better than single-use alternatives?

For many everyday products, it is possible to buy a single or multi-use option. These may be made of plastic or other materials. Examples include coffee cups, cutlery, shopping bags, razors, food wrap and nappies. Extending this idea further, for other types of products it is possible to buy products that are likely to last a lifetime or to opt for alternatives that are less robust and may break after a few years. Examples include fast fashion versus durable shoes and clothing, and cheap versus robust and well-crafted furniture.

It is often assumed that the most environmentally sustainable product is the multi-use or durable option. Is this really the case? Generally a reusable or durable product uses more material in its production and may have environmental impacts to keep it in use (e.g. the energy required to wash the product). Ultimately, the number of times the durable item is used – and therefore the number of single-use items it displaces – will dictate whether it is environmentally preferable to a single-use product. Accumulating many cotton shopping bags or plastic storage boxes in the cupboard at home and failing to use them is not a good result!

ULTIMATELY, THE NUMBER OF TIMES THE DURABLE ITEM IS USED – AND THEREFORE THE NUMBER OF SINGLE-USE ITEMS IT DISPLACES – WILL DICTATE WHETHER IT IS ENVIRONMENTALLY PREFERABLE TO A SINGLE-USE PRODUCT

The key takeaways for life cycle impacts of single-use versus multi-use products are:

- Durable products are likely to be environmentally preferable to single-use disposable alternatives, but only if they are reused enough times to maximise their environmental benefits compared with the alternatives. This is true of plastic and other materials.
- Developing systems where products such as plastic containers are reused could also provide a further benefit in reducing transport-related emissions as less material is transported per unit of service provided by the product to the customer.
- Hygiene and safety issues need to be considered. Factoring in requirements to meet H&S (i.e. washing) may shift net environmental impacts in favour of single-use for some applications, and the risks of contamination may outweigh the benefits in other applications.
- Extending the lifetime of all plastic products is environmentally beneficial in most cases.
- Making reuse the new norm will continue to increase public awareness around resource use and litter, and as people continue to use products as many times as possible it will have environmental benefits.

4.4.1 Case study: Is banning single-use plastic bags the right choice?

Global estimates suggest that 1-5 trillion plastic bags are consumed every year. For scale, 5 trillion bags equates to nearly 10 million bags per minute and, if tied together, these would reach around the world seven times every hour.[451] The excessive use of plastic bags, coupled with concerns over their presence in our natural environment, led to many jurisdictions banning single-use plastic bags, including here in Aotearoa New Zealand from 1 July 2019.[452] Since the ban on single-use plastic shopping bags was announced by the Ministry for the Environment, there has been a lot of public interest in whether the evidence shows that the alternative options are really a better choice for the environment. Is a single-use plastic bag better or worse than alternatives such as a paper bag, a heavier reusable plastic bag or a cotton bag?

There is no clear answer to this question. All bags have environmental impacts from resource extraction, the amount of material used, how it is produced and how it is managed at end-of-life. The most environmentally favourable bag choice will be dictated by the environmental impacts of most concern and how many times a person is likely to reuse the bag.

To date, most LCA studies on shopping bags have not accounted for litter – but litter is one of the major concerns driving plastic bag bans. A recent LCA study comparing HDPE (#2), LDPE (#4), PP (#5), paper and biodegradable plastic bags introduced a littering indicator to model littering, by calculating the relative risk between the different options,rather than assigning a final impact.[453]

The study found that the order of environmental favourability for the climate change impact (determined as part of an LCA study) was the opposite to the order determined by the littering potential indicator (see Table 23). A reusable plastic bag had the lowest impacts for climate change and all impact categories, but was the second-worst for littering potential.

Table 23 Comparison between bag types ranked from best to worst for global warming potential and littering potential

Global warming potential		Littering potential	
BEST	Reusable LDPE bag (at least 10 uses)	Reusable PP woven bag with 40% recycled content (at least 20 uses)	**BEST**
	Single-use HDPE bag (1 use + bin liner)	Single-use recycled paper bag (1 use)	
	Single-use biodegradable bag (1 use)	Single-use biodegradable bag (1 use)	
	Reusable PP woven bag with 40% recycled content (at least 20 uses)	Reusable LDPE bag (at least 10 uses)	
WORST	Single-use recycled paper bag (1 use)	Single-use HDPE bag (1 use + bin liner)	**WORST**

This study is one of the first to factor in littering impacts to a bag LCA. Further studies in different contexts and inclusion of other bags (e.g. cotton reusable bags) are needed to address limitations in this initial study, including factoring in that biodegradable bags act the same as single-use plastic bags and could also be used as a bin liner. Use as a bin liner would reduce the likelihood of litter, as the liner would be disposed in landfill with the bag of waste.

Ultimately, the study demonstrates that there are discrepancies between the best bag choices depending on whether you prioritise ‘climate’ vs ‘litter’, but overall, the best environmental outcomes will come from extensive reuse of a bag and appropriate disposal at its end-of-life. Further complexities around bag choice would come from adding other considerations such as health and economics, into the decision.

[451] UNEP, "Single-Use Plastics: A Roadmap for Sustainability", 2018
[452] Ministry for the Environment, "Proposed Mandatory Phase out of Single-Use Plastic Shopping Bags: Consulation Document", 2018
[453] Civancik-Uslu et al., "Life Cycle Assessment of Carrier Bags and Development of a Littering Indicator," *Science of The Total Environment* 685 (2019)

THERE ARE DISCREPANCIES BETWEEN THE BEST BAG CHOICES DEPENDING ON WHETHER YOU PRIORITISE 'CLIMATE' VS 'LITTER', BUT OVERALL, THE BEST ENVIRONMENTAL OUTCOMES WILL COME FROM EXTENSIVE REUSE OF A BAG AND APPROPRIATE DISPOSAL AT ITS END-OF-LIFE

The social aspects of a product ban are not factored into studies of life cycle environmental impacts and littering impacts. Once awareness had been raised by those campaigning to ban the bag, the changing practice was largely driven by the forces of social contagion (see Section 2.8) and has provided educational value in terms of raising awareness around plastic pollution and helping shift people's attitudes towards sustainability thinking, which is a critical part of the cultural transformation required for rethinking plastics (as discussed in Chapter 2).

4.5 Should we switch to bio-based plastics?

Moving to renewable sources for materials is an important aspect of establishing a circular economy. For plastics, this involves reducing the use of non-renewable fossil-fuel feedstocks and increasing the use of renewable bio-based feedstocks (as discussed in Section 3.7). Note that bio-based plastics are not necessarily biodegradable and vice versa, and sometimes a bio-based plastic can directly replace the fossil-fuel based counterpart (discussed in Section 1.2.4).

As technology advances for the production and use of bio-based plastics, we need to consider whether the environmental profiles of these plastics are better than their fossil-based counterparts, and also whether there are secondary environmental impacts associated with displacement of other activities. For example, potential future feedstocks for bio-based plastics may currently be used as food sources, and the consequence of diverting these feedstocks to bio-based plastic production needs to be considered when determining whether it is a sustainable source for plastics production. Lessons should be learned from the food shortages that have resulted from generating biodiesel.[454] One way to avoid this is by using waste products as a biomass feedstock for plastic materials.

LESSONS SHOULD BE LEARNED FROM THE FOOD SHORTAGES THAT HAVE RESULTED FROM GENERATING BIODIESEL. ONE WAY TO AVOID THIS IS BY USING WASTE PRODUCTS AS A BIOMASS FEEDSTOCK FOR PLASTIC MATERIALS

It is also important to weigh up the benefits of switching to a more sustainable feedstock for plastics with the costs of displacing types of plastic that could be recycled, particularly those that can be recycled onshore. The complexity around whether bio-based plastics are better for the environment than fossil-based plastics is illustrated in Case Study 4.5.1, based on an infographic developed by Kirsten Edgar at Callaghan Innovation.[455]

The key takeaways for life cycle thinking related to bio-based plastics are:

- At present, bio-based plastics are not necessarily environmentally better than fossil-fuel based plastics or other types of materials – it depends upon what the plastic is made from, how it is produced and how it will be managed at end-of-life.[456] Trade-offs should be evaluated using LCA studies. Shifting to 100% bio-based plastics in conjunction with other changes may reduce the carbon footprint of plastics in the future (see Case Study 4.6.1).
- For bio-based plastics, a systems-based analysis of potential feedstocks is necessary to ensure net environmental and other sustainability benefits. This needs to factor in the full life cycle of the product, including whether it is biodegradable (e.g. PLA) or can 'drop-in' to existing recycling processes (e.g. bio-PET (#1)).
- Certain applications of bio-based biodegradable plastics may have co-benefits such as reducing food waste or reducing impacts of litter or plastic pollution, which should be considered alongside LCA findings if not factored in explicitly.

[454] Chakrabortty, "Secret Report: Biofuel Caused Food Crisis", *The Guardian*, 3 July 2008
[455] The dynamic infographic can be viewed at https://infogram.com/biopet-1hxr4zl9rvly6yo
[456] Infrastructure, "Biobased Plastics in a Circular Economy: Policy Suggestions for Biobased and Biobased Biodegradable Plastics", 2017

4.5.1 Case study: Plastics – is plant-based really greener?

Increasingly, plastics are being advertised as 'made from plants', with the implication that it is better for the planet. But is this really true? Chen et al. used LCA to compare the environmental impacts from resource extraction to manufacture (cradle to factory gate – not comparing end-of-life options) for types of PET (#1) plastic with varying proportions of biomass or fossil fuel feedstock (further details around bio-PET (#1) were discussed in Section 3.7).[457] The study considered what the plastic was made from (fossil fuels, corn or woody waste from forestry), how far it was shipped, and its properties (i.e. does it take more material to do the same job).

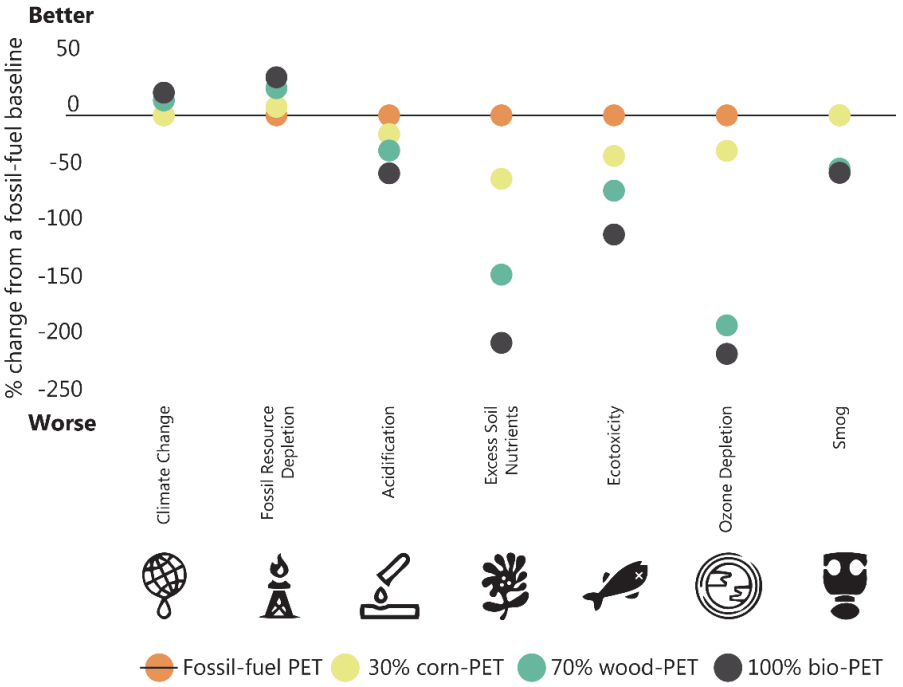

Figure 44 Comparison between PET made from different combinations of fossil fuels or plant matter modelled on the USA data for energy mix, accepted forestry practices, and travel distance from cradle to factory

The analysis identified that there is not a clear answer – the type of material with the best and worst impacts changes depending on which impact is measured (see Figure 44). It is important to use studies like this one to guide decisions, based on the impacts that are prioritised as being most important. The reason the results differ by type include:

- Converting a plant to a plastic sequesters carbon in a solid form
- Agricultural and forestry machinery is fossil-fuelled, which impacts on climate change, ozone depletion and smog
- Power in the US (where the study is from) is mostly fossil-fuel-based, impacting climate change, ozone depletion and smog creation (note that because Aotearoa New Zealand has high rates of renewable electricity this would be much less of an issue here)
- Current processes to convert lignocellulose (wood) to PET (#1) precursors are energy and chemical intensive, with negative impacts on most environmental categories
- Fertilisers and pesticides for crops require energy to make, and have negative impacts on acidification, soil nutrients and ecotoxicity.

In the future, bio-based plastics may have a reduced environmental impact thanks to an increase in use of renewable electricity; industrialisation of microbial processes to convert biomass which reduces the energy and chemicals required to do this; and development of better ways to collect and repurpose a variety of waste streams that could minimise the need to use dedicated crops.

[457] Chen et al., "Comparative Life Cycle Assessment of Fossil and Bio-Based Polyethylene Terephthalate (Pet) Bottles," *Journal of Cleaner Production* 137 (2016)

4.6 Is recycled plastic actually better for the environment?

Increasing the recyclability of plastic and use of recycled plastic is a fundamental aspect of transitioning towards a circular economy. There is likely to be a marked increase in the use of recycled content in packaging in the coming years because it is one of the commitments in the packaging declarations that many Aotearoa New Zealand businesses and the New Zealand Government have signed.[458] The process of recycling plastic uses a number of resources, each with associated environmental impacts – energy is used to power the machinery to separate plastics, water is used to wash flakes, energy is used to melt separated plastics and form it into nurdles (pellets), and fuel is used to transport recycled plastic to and from recycling facilities. Comparing these impacts against those associated with producing virgin resin can inform how the environmental impacts differ between the two and in which contexts it might be favourable to use virgin versus recycled resin.

The main considerations for the life cycle impacts for recycled versus virgin resin are:

- Recycling plastic is likely to be environmentally beneficial, but there needs to be a demand to use the material. Contamination of plastic waste streams with other materials or with types of plastic that cannot be recycled may reduce the efficiency of the process and increase environmental impacts. The worst outcome is to have the environmental impacts of the process outweigh the benefits.
- The source of energy used in the manufacture and recycling process has a significant bearing on the environmental impacts. The majority of Aotearoa New Zealand's electricity is generated from renewable sources, so recycling plastic is likely to be environmentally beneficial here.[459] Whether this is true of imported virgin or recycled resin will depend on the energy sources of the country of origin.
- The distance between material collection and recycling facilities will also have a significant bearing on the environmental impacts through energy used for transport. The large transportation distances that may be required due to the low population and limited number of MRFs and/or recycling facilities may increase emissions for recycled plastic in Aotearoa New Zealand. The rail network is unlikely to present a solution given the logistical issues of where waste would need to be transported in order to be loaded onto the network (as discussed in Case Study 3.8.1).
- The source of feedstock is an important driver of the carbon footprint of bio-based plastics (discussed in Section 4.5).
- The potential health and toxicological impacts associated with chemical additives in the recycled plastic (discussed in Section 4.14 and Section 4.19) are not factored into LCA studies and must be considered depending on the application of the recycled material.

[458] In both the New Zealand Plastic Packaging Declaration of June 2018 and the New Plastics Economy Global Commitment, signatories pledge to use 100% reusable, recyclable or compostable packaging in NZ operations by 2025.
[459] Ministry for Business, "Energy in New Zealand", 2019

4.6.1 Case study: Reducing the carbon footprint of plastics by using recycled plastic

In a study of the carbon footprint of projected global plastic use between 2015 and 2050, Zheng and Suh modelled a theoretical situation of 100% recycling of plastic in 2050, and found it had a 25% lower carbon footprint in 2050 relative to the current trajectory (business-as-usual) of plastic use up to 2050.[460] An even greater reduction could potentially be achieved by focusing on transitioning to renewable energies for use in plastic manufacture or by reducing demand for plastic in the economy manufactured by current methods. Recycling plastic was generally better than, or similar to, the benefits of moving to bioplastics (depending upon the feedstocks and certain other conditions). The greatest reduction in the carbon footprint came from implementing a mix of all these activities: the carbon footprint of plastics use in 2050 could be reduced by 93% (relative to the current trajectory up to 2050) by moving to 100% sugarcane-based plastics with 100% renewable energy combined with 100% recycling and reduced demand growth. It is important to ensure that efforts to reduce the carbon footprint of plastics, such as using renewable feedstocks like sugarcane, does not displace food sources (see Section 4.5).

THE CARBON FOOTPRINT OF PLASTICS USE IN 2050 COULD BE REDUCED BY 93% (RELATIVE TO THE CURRENT TRAJECTORY UP TO 2050) BY MOVING TO 100% SUGARCANE-BASED PLASTICS WITH 100% RENEWABLE ENERGY COMBINED WITH 100% RECYCLING AND REDUCED DEMAND GROWTH

[460] Zheng et al., "Strategies to Reduce the Global Carbon Footprint of Plastics," *Nature Climate Change* (2019)

4.7 Should we ban plastic packaging altogether?

An extreme response to reduce the use of plastic and its associated environmental impacts would be to ban plastic packaging altogether. As discussed in Chapters 2 and 3, we need to prioritise rethinking systems and reducing our use of plastics, particularly for unnecessary packaging and products. However, before removing plastic packaging, we need to factor in the benefits of packaging that are lost if the packaging is removed and take a 'whole-of-life' approach to environmental impacts. One of the purposes of packaging is to protect the contained product, and so its removal may lead to a higher proportion of damaged or spoiled products. Examples include plastic sleeves around cucumbers and other vegetables or fruit to give them a longer shelf life in supermarkets; plastic liners in cardboard boxes of kiwifruit that are traded internationally contribute to keeping the fruit in good condition over several weeks; and packaging around new consumer goods such as washing machines, televisions and furniture that stop these products being damaged in transit. It is important to be aware of the function of plastic packaging when assessing alternatives, and ensure that any alternatives conserve the functionality of the packaging. Some businesses are currently facing pressure from their customers to move away from plastic packaging, but decisions to remove packaging altogether or shift to a non-plastic packaging should be guided by LCA to avoid creating a worse environmental outcome.

DECISIONS TO REMOVE PACKAGING ALTOGETHER OR SHIFT TO A NON-PLASTIC PACKAGING SHOULD BE GUIDED BY LCA TO AVOID CREATING A WORSE ENVIRONMENTAL OUTCOME

The key points when considering the life cycle impacts of banning plastic packaging are:

- When considering alternatives to plastic packaging, LCA should be used to investigate any trade-offs in net environmental impacts arising from potentially greater wastage of the packaged product when using alternative packaging.
- An unintended consequence of removing plastic packaging may be an increase in emissions due to food waste.
- A supply-chain approach to reducing use of plastic is needed to ensure removing packaging at one stage (e.g. retail) doesn't lead to an increase in environmental impacts (e.g. food waste).
- If plastic is necessary for food preservation, it is imperative that systems are in place to maximise that resource staying in circulation and not leaking into the environment.
- It is not simple! Businesses need support to guide their choices.

4.7.1 Case study: Contribution of packaging to the carbon footprint of breakfast foods

Fresán and colleagues undertook 'cradle-to-gate' carbon footprint studies of six common breakfast foods eaten in southern California: orange juice, milk, instant coffee, breakfast cereals, bread buns and peanut butter.[461] Similar to a number of other LCA studies, they found that the packaging for each of the foods contributed a minor part of the life cycle-based carbon footprint compared with the food production. With a few exceptions, and for a range of different serving sizes, the packaging contributed 10% or less of the total carbon footprint for food production plus packaging. The exceptions were orange juice and breakfast cereals where the packaging carbon footprint was 13 to 35% of this carbon footprint, and bread buns in single-serve packages where the packaging contributed 17% of the carbon footprint. The carbon footprint of the paper packaging was lower than the plastic packaging, and glass packaging had the highest carbon footprint. However, the authors noted that the different properties of these materials need to be considered when choosing a packaging material; for example, paper and plastic are lightweight, plastic is flexible, and glass is inert and impermeable.

THE PACKAGING FOR EACH OF THE FOODS CONTRIBUTED A MINOR PART OF THE LIFE CYCLE-BASED CARBON FOOTPRINT COMPARED WITH THE FOOD PRODUCTION. THE PACKAGING CONTRIBUTED 10% OR LESS OF THE TOTAL CARBON FOOTPRINT FOR FOOD PRODUCTION PLUS PACKAGING

[461] Fresán et al., "Does the Size Matter? A Comparative Analysis of the Environmental Impact of Several Packaged Foods," *Science of The Total Environment* 687 (2019)

4.8 Should we use an alternative material to plastic?

As discussed in Chapters 1 and 2, public concern over plastic is growing and therefore pressure is mounting on brands to change materials, particularly for packaging. The question of whether to replace plastic with an alternative material such as cardboard, metal, glass or a multi-material option is arising in many businesses. Where packaging is deemed to be necessary, businesses need support to determine what the ideal packaging material is for their products. LCA can be used to inform material choice for a specific application by evaluating and comparing the full life cycle environmental impact of different options, including different end-of-life options. Such an analysis may demonstrate that in the Aotearoa New Zealand context, a plastic bottle made of PET (#1) has lower environmental impacts compared to a glass bottle, or it may indicate the opposite. In general, LCA comparisons should be undertaken at the application level rather than at the material level because these will draw a complete picture of the environmental impacts over the product's life cycle. This is important because there might be environmental impact hotspots in the life cycle that are more important than the impacts of material production – as illustrated with food waste in Case Study 4.7.1.

The key takeaways related to life cycle thinking when replacing plastic with an alternative material are:

- Plastic may or may not be the best material choice for a product from a life cycle based environmental perspective – it depends on the context and the alternatives available, and should be assessed using LCA.
- Plastic is lighter than many other materials, such as glass, steel and concrete, and so may be preferred when the environmental hotspots of a product are associated with transportation (e.g. international transport of some food products with plastic packaging, body parts for vehicles).
- Because environmental leakage is not currently factored into standardised LCA methodology, we need to explicitly consider the evidence related to the impacts of plastic leaking into the environment alongside the evidence from LCA. Non-marine-biodegradable plastic is unlikely to be the best material choice for a product where there is a high likelihood that it will leak into the environment after use and end up in the ocean (discussed later in this chapter).

4.8.1 Case study: Should wine bottles be plastic?

In LCAs of wine, the analysis extends from growing grapes through to winemaking, and on to distribution, consumption and end-of-life management of the empty wine bottle. The production and transport of the wine bottle itself is an environmental hotspot in the life cycle of wine both internationally [462] and in Aotearoa New Zealand. [463] In order to reduce these environmental impacts associated with the wine bottle, researchers have investigated the use of alternative packaging, including plastic bottles and aseptic cartons. Other initiatives include light-weighting glass bottles (i.e. manufacturing them with less glass), and transportation of wine in bulk and then packaging it into bottles closer to market. LCA studies have shown that plastic bottles and aseptic cartons reduce the climate change impacts of wine bottles, as does light-weighting glass bottles and bulk transportation.[464] However, care must be taken with these alternatives to ensure the quality and value of the wine is maintained. Local recycling options should also be considered.

Figure 45 An example of a plastic wine bottle developed by Yealands. Source: Yealands.

[462] Ferrara et al., "Life Cycle Assessment Application to the Wine Sector: A Critical Review," *Sustainability* 10, no. 2 (2018)
[463] Barry et al., "Life Cycle Assessment and the New Zealand Wine Industry : A Tool to Support Continuous Environmental Improvement : A Thesis Presented in Partial Fulfilment of the Requirements for the Degree of Master of Environmental Management in Life Cycle Management at Massey University, Wellington, New Zealand" (Masters, Massey University, 2011)
[464] Ferrara et al., "Life Cycle Assessment Application to the Wine Sector: A Critical Review,"

4.9 Should we restrict our use of plastic to certain types?

For most brands, the cost of manufacturing the product generally dictates material choice but ideally life cycle thinking would be used to guide these choices. Though it is better to perform LCA for an application rather than the material on its own. However, there are many instances, particularly in packaging, where several types of plastic could be used and the main difference in environmental impact comes from the available end-of-life options. Thinking about whether the material can and will be recycled might drive brands to use PET (#1), which has an onshore closed-loop recycling system and a good market for the recycled plastic (see Case Study 3.6.8), rather than PVC (#3) or PS (#6), which have neither.

THINKING ABOUT WHETHER THE MATERIAL CAN AND WILL BE RECYCLED MIGHT DRIVE BRANDS TO USE PET (#1), WHICH HAS AN ONSHORE CLOSED-LOOP RECYCLING SYSTEM AND A GOOD MARKET FOR THE RECYCLED PLASTIC, RATHER THAN PVC (#3) OR PS (#6), WHICH HAVE NEITHER

There are other times where changing to an alternative plastic, even one that has an onshore recycling solution, wouldn't be environmentally beneficial because it would require using more plastic material or using additives that limit future recyclability of that plastic. For example, to effectively store ice cream in a freezer, a PET (#1) container would need far more material than the PP (#5) containers currently used, which are also better suited for products that are hot when packaged.

The key takeaways when thinking about life cycle impacts of restricting use to certain types of plastic are:

- Decisions about restriction of plastic types should be supported by LCA studies of the alternatives that identify any trade-offs in net environmental impacts associated with production and use of alternative materials, recyclability of alternative materials, greater wastage of the packaged product, etc. for the Aotearoa New Zealand context. One implication of restricting to certain types of plastic is that it will funnel use and improve economies of scale for more favourable types, further reducing environmental impacts.
- Considering these factors in the current Aotearoa New Zealand context, the types of plastic with the lowest environmental footprint are likely to be PET (#1), HDPE (#2) and PP (#5) because there is onshore reprocessing capability and a strong market for these materials to be pulled through and used again, which is key for reducing the impacts of the plastic (see Section 4.6).

IN THE CURRENT AOTEAROA NEW ZEALAND CONTEXT, THE TYPE OF PLASTIC WITH THE LOWEST ENVIRONMENTAL FOOTPRINT IS LIKELY TO BE PET (#1), HDPE (#2) AND PP (#5) BECAUSE THERE IS ONSHORE REPROCESSING CAPABILITY AND A STRONG MARKET FOR THESE MATERIALS

4.10 What end-of-life options for plastic are best for Aotearoa New Zealand?

LCA can be used to evaluate the environmental impacts of systems as well as products. It is an alternative approach to the widely cited waste hierarchy framework that is predominantly used to guide waste management policies (described in Section 1.3.3). The waste hierarchy is based on end-of-life options for a product rather than the whole-of-life environmental impacts considered in LCA, and does not account for the context in which waste management decisions take place. For example, recycling cannot take place unless recycling schemes exist, and even then it may not be possible if recycled materials are contaminated. These two approaches can be used together guide decisions around plastic use.

The key considerations when thinking about the life cycle impacts of end-of-life options for plastic in Aotearoa New Zealand are:

- The waste hierarchy is generally appropriate to guide end-of-life management of plastic products but this may not be the case for specific applications or contexts.
- LCAs should be used to investigate situations where there may be greater environmental impacts associated with reducing, reusing or recycling products at end-of-life.
- Decisions about end-of-life management for plastics should be based on priority environmental impacts – right now this might mean reducing plastic pollution and mitigating climate change.
- Landfills are not a long-term solution for plastic waste but modern landfills may be an appropriate interim measure while we transition to zero plastic waste (see Case Study 3.8.1).

4.10.1 Case study: Is landfill or incineration of plastic waste preferable?

A UK study found that separating plastics in household waste for recycling was a better environmental option than incineration in a waste-to-energy facility.[465] Nevertheless, if contaminated and mixed plastic cannot be recycled into high quality recyclate, it remains an open question as to whether it should be landfilled or incinerated in a carefully controlled environment with energy capture (also called thermal valorisation). In line with the waste hierarchy, LCA studies indicate that landfilling of waste is generally the worst end-of-life management option. However, it could be argued that landfilling represents a way of sequestering the carbon in the plastic; alternatively, this can be regarded as unsustainable because it passes the problem of plastic waste management on to future generations.

There are no publicly available LCAs assessing whether landfill or incineration with energy capture is a better environmental option for Aotearoa New Zealand. Such a study would be needed to better understand the relative environmental performance of each option in our local context – particularly since the results would be influenced by the transportation requirements between points of waste generation and incineration plants or landfills.

THERE ARE NO PUBLICLY AVAILABLE LCAS ASSESSING WHETHER LANDFILL OR INCINERATION WITH ENERGY CAPTURE IS A BETTER ENVIRONMENTAL OPTION FOR AOTEAROA NEW ZEALAND

The conclusions may also change depending on new materials and new technology. Right now, we would have to factor in that the economics of incineration plants would probably mean that only one or two plants would be feasible around the country and therefore there would be emissions related to transport. In the future, if smaller scale plants were economic that would change the outcomes, as would an electric vehicle fleet powered by renewable energy. Alternatively, there may be an increase in biodegradable or compostable plastics that enter landfill, and outcomes of the analysis may change, particularly if all waste was disposed to modern landfills with methane capture.

[465] Burnley and Coleman (2018)

4.11 Summary and recommendation

LCA is a tool that should be used alongside information from others in the toolbox to inform decisions. For example, one of the biggest issues related to plastic – the negative impact on ecosystems when leaked into the environment – isn't currently addressed in LCA. While there are unacceptable leakages in the system, as evidenced by the worldwide build-up of plastic debris and widespread presence of microplastics, these impacts must also be considered during product choice. These are not simple to incorporate into LCAs as there is as yet no agreed value for environmental damage, but work is underway to standardise this (as discussed in Section 4.3). Currently we simply don't know (beyond anecdotally) how big the impact is of plastic in the environment. In Section 4.12, we outline the evidence to date.

The evidence for life cycle environmental impacts of plastic need to be considered alongside the social, technical, health and economic aspects of material choice. As yet, these are also not factored into LCA studies and need to be part of the decision-making process. In the context of using LCAs as a tool to support policy decisions, it is important to perform sensitivity analyses with different scenarios to understand potential changes in outcome.

THE EVIDENCE FOR LIFE CYCLE ENVIRONMENTAL IMPACTS OF PLASTIC NEED TO BE CONSIDERED ALONGSIDE SOCIAL, TECHNICAL, HEALTH AND ECONOMIC ASPECTS OF MATERIAL CHOICE

It is also important to scrutinise the LCAs used to inform decisions. How accurate and relevant the LCA findings are depends on the quality of the input data and the context of the study. For example, it may not be appropriate to base decisions for Aotearoa New Zealand's use and disposal of plastics on LCA studies completed in a European context when the logistics of transport and end-of-life disposal options are quite different. Caveats should be noted when drawing on studies undertaken for a different context. It may be possible to adapt overseas LCA data in order to partially address the Aotearoa New Zealand context – however, in general more robust results will be obtained from developing a local dataset because our transport, infrastructure, electricity generation, and imports and exports are all quite unique. Quality, localised data are crucial to ensuring the LCA findings provide robust evidence to support decision making to reduce environmental impacts. There are big data gaps and a lack of publicly available LCA studies related to plastics in Aotearoa New Zealand. The need for high-quality local input data for LCA studies to inform rethinking plastics highlights the need for rigorous local pilot data gathering (discussed further in Chapter 5). We need to model the Aotearoa New Zealand situation and support businesses and policymakers to make decisions based on these studies, with guidance from people with expertise in LCA.

Life cycle assessments should be used as part of decision-making processes around plastic policy, product redesign, and waste management systems. We need to be guided by evidence that is relevant for our situation in Aotearoa New Zealand. The environmental impacts associated with a product very much depend on the local context – such as the logistics of transport or whether recycling is available – so, in evaluating the evidence from studies in other countries, we should consider whether the context is similar to Aotearoa New Zealand or whether local studies are necessary. This is addressed within recommendation 3.

Key considerations for implementing this recommendation:

- A centralised database of NZ LCA datasets that is accessible to everyone could facilitate LCA studies in Aotearoa New Zealand. The Building Research Association of New Zealand (BRANZ) has published datasheets on transportation distances for construction materials, wastage rates on construction sites, etc. that can be used in New Zealand LCA studies, which could be used as a model for plastics and packaging.[466]
- Linking with international initiatives on standardised dataset provision will enhance usefulness, credibility and uptake of NZ datasets e.g. forming a node linked to the United Nations' Global LCA Data Access network (GLAD)[467]
- Simplified decision-support tools based on LCAs may be appropriate for some sectors. For example, LCAQuick is designed for architects, designers, and structural engineers to use early in the building design process.[468]
- The Australasian EPD Programme[469] has experience in supporting and promoting NZ LCA studies, and can provide insights and expertise.

[466] BRANZ, "New Zealand Whole-Buildling Whole-of-Life Framework: Development of Datasheets to Support Building Life Cycle Assessment", 2016
[467] More information available at: https://www.globallcadataaccess.org/about
[468] More information available at: https://www.branz.co.nz/lcaquick
[469] More information available at: https://epd-australasia.com/

4.12 Impacts of plastic leaked into our environment

KO AU TE MOANA
KO TE MOANA KO AU[470]

Plastic debris has been identified throughout the environment – from air to land to remote uninhabited islands to the deepest trench in the ocean. Plastic pollution is pervasive. The majority of studies measuring plastic pollution in the environment have been undertaken overseas with several estimating the amount of plastic pollution on a global scale. A study by Jambeck et al. in 2015 calculated that of the 275 million tonnes of plastic waste generated in 192 coastal countries in 2010, 4.8-12.7 million tonnes entered the ocean.[471] It is estimated that 80% of marine plastic debris comes from land and only 20% from ocean-based sources, with commercial fisheries being a large contributor.[472] A study of how land-based plastic debris reaches the ocean through rivers estimated that 88-95% of the global load of ocean plastics is transported through 10 large rivers with population-rich catchments.[473]

The highest reported density of plastic debris anywhere in the world was on Henderson Island, a remote island in the South Pacific, with up to 670 items/m^2 on the surface of beaches in 2017.[474] More recently, it was reported that around 25% of the 400 million anthropogenic debris items on the remote Cocos (Keeling) Islands 2100 km northwest of Australia were disposable plastics.[475] Plastic waste was also identified on the seafloor of the Pacific Ocean's Mariana Trench – the deepest place in the ocean.[476]

Current estimates give us an idea of the scale of plastic waste that has already been littered into our environment, but beyond high-level estimates we don't know the amounts and types of plastic in the ocean. These estimates also highlight that the issue of plastic pollution reaches much further than what we can see – of the 86 million tonnes thought to have ended up in the sea, it is estimated that only around 0.5% is floating at the surface, with the rest below the surface or at the bottom of the ocean.[477] Studies estimating the volume of plastic debris on the ocean surface have discrepant findings due to different methods.[478] One study estimated between 7,000–35,000 tonnes on the sea surface,[479] while another estimated 93,000–236,000 tonnes.[480]

OF THE 86 MILLION TONNES THOUGHT TO HAVE ENDED UP IN THE SEA, IT IS ESTIMATED THAT ONLY AROUND 0.5% IS FLOATING AT THE SURFACE WITH THE REST BELOW THE SURFACE OR AT THE BOTTOM OF THE OCEAN

The field of research identifying the impacts of plastic in the environment is relatively new and there have been many efforts to review the current evidence-base. The main focus of this chapter is to highlight evidence that is particularly relevant to support policy decisions that aim to reduce or prevent the impacts associated with plastic pollution for Aotearoa New Zealand (see Section 5.9 for a summary of the evidence quantifying the presence of micro and macro plastic debris in Aotearoa New Zealand).

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[470] I am the ocean; the ocean is me
[471] Jambeck et al., "Plastic Waste Inputs from Land into the Ocean," *Science* 347, no. 6223 (2015)
[472] Li et al., "Plastic Waste in the Marine Environment: A Review of Sources, Occurrence and Effects,"
[473] Schmidt et al., "Export of Plastic Debris by Rivers into the Sea," *Environmental Science & Technology* 51, no. 21 (2017)
[474] Lavers et al., "Exceptional and Rapid Accumulation of Anthropogenic Debris on One of the World's Most Remote and Pristine Islands," *Proceedings of the National Academy of Sciences of the United States of America* 114, no. 23 (2017)
[475] Lavers et al., "Significant Plastic Accumulation on the Cocos (Keeling) Islands, Australia," *Scientific Reports* 9 (2019)
[476] Morelle, "Mariana Trench: Deepest-Ever Sub Dive Finds Plastic Bag", *BBC*, 13 May 2019
[477] UNEP, "Marine Litter Vital Graphics", 2016
[478] UK Government Office for Science, "Future of the Sea: Plastic Pollution", 2017
[479] Cozar et al., "Plastic Debris in the Open Ocean," *Proceedings of the National Academy of Sciences of the United States of America* 111, no. 28 (2014)
[480] van Sebille et al., "A Global Inventory of Small Floating Plastic Debris," *Environmental Research Letters* 10, no. 12 (2015)

We cover the following issues with a brief summary of available evidence, what it means for our local context, and possible actions to be taken:

- Plastic causes physical harm to marine life and other species
- Additional risks come from chemicals added to plastic
- We don't fully understand the impacts caused by microplastics
- We know less about the impact of even smaller plastic particles (nanoplastics)
- Plastic pollution poses a biosecurity risk
- Plastic may contribute to antimicrobial resistance
- Plastic may impact human health and wellbeing.

Figure 46 Goat Island, Leigh, Aotearoa New Zealand

4.13 Plastic causes physical harm to marine life and other species

There is extensive evidence that plastic pollution harms marine life and seabirds by causing injury or death through entanglement or ingestion of plastic debris.[481] It is estimated that plastic waste kills up to 1 million seabirds, 100,000 sea mammals and marine turtles, and countless fish each year.[482] There are documented encounters of 800 species with marine litter, the majority being plastic, which include every species of turtle, 66% of marine mammal species and 50% of seabird species.[483] Physical harm can also be caused by plastic-related habitat change. These impacts are described in detail in the Royal Society Te Apārangi report on plastics in the environment[484] and Marine Litter Vital Graphics by the UNEP, which summarises the evidence of the scale, ecological impacts, economic and social costs, human health threat and possible policy responses.[485]

IT IS ESTIMATED THAT PLASTIC WASTE KILLS UP TO 1 MILLION SEABIRDS, 100,000 SEA MAMMALS AND MARINE TURTLES, AND COUNTLESS FISH EACH YEAR

The biggest concerns are that:

- **The effects are widespread.** Ingestion of plastic affects the whole food chain and recent evidence suggests that several species show a preference for ingesting plastics over their natural food source.[486]
- **It negatively affects biodiversity.** Plastic ocean debris is contributing to a decline in marine biodiversity.[487]
- **We don't know the extent of the impacts.** There are significant knowledge gaps and new ways that plastic physically impacts the environment are still being discovered. For example, researchers identified a new type of plastic pollution that is encrusted onto tidal rocky shores – now known as plasticrust, which may be a new way for plastic to enter the marine food web.[488] A new type of marine litter resulting from plastic that has been burned, which looks like rocks on the beach, has also been identified.[489]
- **The problem will compound.** Plastic is accumulating in the environment because it takes such a long time to break down, so the environmental risks will continue to increase as plastic pollution becomes more pervasive, unless serious efforts are made to eliminate and remediate plastic pollution.

[481] Wilcox et al., "Threat of Plastic Pollution to Seabirds Is Global, Pervasive, and Increasing," *Proceedings of the National Academy of Sciences of the United States of America* 112, no. 38 (2015)
[482] UN Oceans Conference Factsheet available at: https://sustainabledevelopment.un.org/content/documents/Ocean_Factsheet_Pollution.pdf
[483] UNEP, "Plastics and Shallow Water Coral Reefs: Synthesis of the Science for Policy-Makers", 2019
[484] Royal Society Te Apārangi, "Plastics in the Environment: Te Ao Hurihuri – the Changing World", 2019
[485] UNEP, "Marine Litter Vital Graphics", 2016
[486] Rotjan et al., "Patterns, Dynamics and Consequences of Microplastic Ingestion by the Temperate Coral, <I>Astrangia Poculata</I>," *Proceedings of the Royal Society B: Biological Sciences* 286, no. 1905 (2019)
[487] The WWF estimate that there was a 49% decline in marine biodiversity between 1970 and 2012. Plastic pollution is a stressor that contributes to this decline along with overfishing, aquaculture, tourism, oil and gas extraction, and climate change World Wildlife Fund, "Living Blue Planet Report: Species, Habitats and Human Well-Being", 2015. However, the UK Government for Science notes there is an in-built tendency for the time series method used in these analyses to show declining trends.
[488] Gestoso et al., "Plasticrusts: A New Potential Threat in the Anthropocene's Rocky Shores," *Science of The Total Environment* 687 (2019)
[489] Turner et al., "Marine Pollution from Pyroplastics," *Sci Total Environ* 694 (2019)

4.13.1 What this means for Aotearoa New Zealand

Despite our remoteness and established waste management systems, Aotearoa New Zealand's local wildlife is not immune to physical harm from plastic pollution. There is evidence that plastic harms our local and native species, some of which are already endangered. We don't know the extent of every species that is impacted by plastics in Aotearoa New Zealand, but a handful of studies have demonstrated that ingestion and entanglement have caused harm to endangered green turtles,[490] seabirds,[491] fish,[492] and fur seals.[493] In fact, the rates of entanglement for the fur seals in Kaikoura were among the highest reported in the world. Further research is underway to quantify plastic ingestion in local wildlife (see Appendix 6).

THE RATES OF ENTANGLEMENT FOR THE FUR SEALS IN KAIKOURA WERE AMONG THE HIGHEST REPORTED IN THE WORLD

Seabirds are particularly important to consider – we are home to one-third of all species of seabird and the breeding ground for the highest number of seabird species worldwide. Because of this, plastic debris in our seas poses a higher risk to seabird populations and efforts to protect these species and their ecosystems by preventing plastic in the environment are crucial.[494] As part of practising kaitiakitanga (discussed in Section 1.3.1), it is important that further research analyses the risks to native and taonga species and how to protect them.

4.13.2 Actions that could reduce physical harm to marine life

- Ban or redesign problematic products that are known to cause harm because of being mistaken for food (e.g. clear plastic bags resemble jellyfish and are ingested by turtles, and bottle lids and smaller fragments are mistaken by seabirds as prey items[495]) – guided by data (Chapter 5) and innovations (Chapter 3)
- Determine local sources of plastic pollution and direct efforts to stop at source (see Section 4.20.1)
- Coordinate efforts with international programmes to reduce plastic leaking into the environment (see Section 1.2.1)
- Undertake research to address knowledge gaps not yet being addressed in local studies (see Section 4.22).

[490] Godoy et al., "Anthropogenic Impacts on Green Turtles Chelonia Mydas in New Zealand," *Endangered Species Research* 37 (2018)
[491] Buxton et al., "Incidence of Plastic Fragments among Burrow-Nesting Seabird Colonies on Offshore Islands in Northern New Zealand," *Marine Pollution Bulletin* 74, no. 1 (2013)
[492] Markic et al., "Double Trouble in the South Pacific Subtropical Gyre: Increased Plastic Ingestion by Fish in the Oceanic Accumulation Zone," *Marine Pollution Bulletin* 136 (2018)
[493] Boren et al., "Entanglement of New Zealand Fur Seals in Man-Made Debris at Kaikoura, New Zealand," *Marine Pollution Bulletin* 52, no. 4 (2006)
[494] Forest & Bird, "Nz Seas Worst in World for Seabirds Eating Plastic", press release, 2 July 2018
[495] Buxton et al., "Incidence of Plastic Fragments among Burrow-Nesting Seabird Colonies on Offshore Islands in Northern New Zealand," *Marine Pollution Bulletin* 74, no. 1 (2013)

4.14 Additional risks come from chemicals added to plastic

One of the ways plastic pollution can impact the environment is through leaching of chemical additives – a considerable number of which are toxic – that are included in the polymer mix to give the plastic specific properties.[496] Through this leaching process, plastic contributes to the exposure of organisms to hazardous chemicals. The associated risks of these chemicals entering the environment are directly related to plastic pollution and should be considered when rethinking plastics.

Some of the common chemical additives are 'endocrine disrupting chemicals' (EDCs), meaning they disrupt hormonal processes. Other common chemicals are 'persistent organic pollutants' (POPs) that are resistant to environmental degradation, so the concentrations will accumulate in the environment. The risks of toxic chemicals associated with plastics are discussed in greater detail in the Royal Society Te Apārangi report on plastics in the environment.[497]

The biggest concerns are that:

- **These chemicals can disrupt biological processes.** Most plastic additives are lipophilic, meaning that if plastic is ingested the chemicals can easily move into the organism's membranes and impact biochemical processes. There is early evidence that chemicals from plastic may contribute to population decline of a range of species by causing reduced fertility, fitness, mobility and immunity, increased risk of carcinogenesis, and changes to blood chemistry, hormone levels and gene expression.[498]
- **The concentration of chemicals – and any associated toxicity – can increase up the food chain.** Chemicals can accumulate (i.e. concentrate) in tissues which are then ingested by predators (referred to as bio-magnification). Even a small amount ingested at the lowest level of the food chain (e.g. in zooplankton) may reach biologically-relevant levels as it moves up the food chain, leading to knock-on effects that could impact whole ecosystems. When chemical contaminants are attached to plastic it can inhibit the contaminant from degrading, further increasing concentrations of these chemicals that can potentially enter the food chain.[499]
- **Organisms are likely to be exposed to higher levels than what we currently measure.** The high surface-area-to-volume ratio of microplastics leads to a faster rate of leaching of additives in the plastic and also a faster rate of adsorbing (and concentrating) other contaminants (including bacteria) that are already in the environment. After being swallowed these can desorb from the plastic particles in the gut leading to high rates of exposure.[500] Most reported levels of chemical contaminants are from environmental monitoring and do not account for the increased

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[496] Gallo et al., "Marine Litter Plastics and Microplastics and Their Toxic Chemicals Components: The Need for Urgent Preventive Measures," *Environmental sciences Europe* 30, no. 1 (2018)

[497] Royal Society Te Apārangi, "Plastics in the Environment: Te Ao Hurihuri – the Changing World", 2019

[498] Browne et al., "Microplastic: An Emerging Contaminant of Potential Concern?," *Integrated Environmental Assessment and Management* 3, no. 4 (2007); Bakir et al., "Enhanced Desorption of Persistent Organic Pollutants from Microplastics under Simulated Physiological Conditions," *Environmental Pollution* 185 (2014); Browne et al., "Microplastic Moves Pollutants and Additives to Worms, Reducing Functions Linked to Health and Biodiversity," *Current Biology* 23, no. 23 (2013); Cole et al., "Microplastics as Contaminants in the Marine Environment: A Review," *Marine Pollution Bulletin* 62, no. 12 (2011); Teuten et al., "Transport and Release of Chemicals from Plastics to the Environment and to Wildlife," *Philosophical Transactions of the Royal Society B-Biological Sciences* 364, no. 1526 (2009); Lavers et al., "Clinical Pathology of Plastic Ingestion in Marine Birds and Relationships with Blood Chemistry," *Environmental Science & Technology* (2019); Sussarellu et al., "Oyster Reproduction Is Affected by Exposure to Polystyrene Microplastics," *Proceedings of the National Academy of Sciences of the United States of America* 113, no. 9 (2016); Rochman et al., "Early Warning Signs of Endocrine Disruption in Adult Fish from the Ingestion of Polyethylene with and without Sorbed Chemical Pollutants from the Marine Environment," *Science of the Total Environment* 493 (2014); Cole et al., "The Impact of Polystyrene Microplastics on Feeding, Function and Fecundity in the Marine Copepod Calanus Helgolandicus," *Environmental Science & Technology* 49, no. 2 (2015); Setala et al., "Ingestion and Transfer of Microplastics in the Planktonic Food Web," *Environmental Pollution* 185 (2014); Rochman et al., "Ingested Plastic Transfers Hazardous Chemicals to Fish and Induces Hepatic Stress," *Scientific Reports* 3 (2013)

[499] Duis et al., "Microplastics in the Aquatic and Terrestrial Environment: Sources (with a Specific Focus on Personal Care Products), Fate and Effects," *Environmental Sciences Europe* 28 (2016); Setala et al., "Ingestion and Transfer of Microplastics in the Planktonic Food Web,"; Cole et al., "Microplastics as Contaminants in the Marine Environment: A Review,"; Fossi et al., "Are Baleen Whales Exposed to the Threat of Microplastics? A Case Study of the Mediterranean Fin Whale (Balaenoptera Physalus)," *Marine Pollution Bulletin* 64, no. 11 (2012)

[500] Chubarenko et al., "On Some Physical and Dynamical Properties of Microplastic Particles in Marine Environment," *Marine Pollution Bulletin* 108, no. 1-2 (2016); Nakashima et al., "The Potential of Oceanic Transport and Onshore Leaching of Additive-Derived Lead by Marine Macro-Plastic Debris," *Marine Pollution Bulletin* 107, no. 1 (2016); Bakir et al., "Enhanced Desorption of Persistent Organic Pollutants from Microplastics under Simulated Physiological Conditions,"

rates of exposure in the gut due to these faster rates of adsorption and desorption. Further details around microplastics are discussed in Section 4.15.

- **Removing chemical additives from plastic won't fully resolve the issue.** Even if all plastics didn't have any chemical additives included in the mix, there remains the issue of other chemical contaminants (or bacteria) that are already in the environment adsorbing onto the plastic.[501]
- **Recycled plastic and biodegradable plastic also contribute to the problem.** Recycled plastic may inadvertently carry chemical additives from the source plastic.[502] Unless specifically designed to be marine-biodegradable (see Section 3.7), biodegradable plastics are basically non-degradable in seawater and may also pose a toxicity risk.[503]

4.14.1 What this means for Aotearoa New Zealand

We know that there is plastic pollution in our local environment and that this may bring with it associated toxic effects, but current evidence for levels of chemicals associated with plastic pollution around Aotearoa New Zealand is lacking. One study tested for POPs associated with plastic pellets/nurdles around Australia and Aotearoa New Zealand's North Island, as part of a global monitoring programme called International Pellet Watch.[504] The study identified high concentrations in Auckland and Australia's large cities, and very low concentrations at the tip of the North Island. In the latest survey of groundwater, ESR detected BPA at very low concentrations, which could be contributed to by plastic among other sources.[505]

To better understand the risks to Aotearoa New Zealand and guide decision making, studies need to determine the levels of various chemical contaminants across the country, and the associated exposures for organisms through the food chain, including humans.

4.14.2 Actions needed to reduce risk related to plastic additives

A review of the toxic chemical components of marine litter plastics and microplastics to inform the working groups for the Stockholm and Basel Conventions concluded that there is a need for urgent preventative measures to reduce ongoing risk from chemicals added to plastic.[506]

Priority measures include:

- Preventing plastic leaking into the environment (see Section 4.20.1)
- Identifying the additives or products that pose the highest risk of toxicity and using lower risk replacements
- Drawing on international studies and evidence of the impacts of chemicals associated with plastic
- Undertaking research to address knowledge gaps not yet being addressed in local studies (see Section 4.22), including initiating studies of plastic-associated POPs and EDCs at various locations throughout Aotearoa New Zealand.

[501] Teuten et al., "Transport and Release of Chemicals from Plastics to the Environment and to Wildlife,"; Nakashima et al., "The Potential of Oceanic Transport and Onshore Leaching of Additive-Derived Lead by Marine Macro-Plastic Debris,"; Ashton et al., "Association of Metals with Plastic Production Pellets in the Marine Environment," *Marine Pollution Bulletin* 60, no. 11 (2010); Ogata et al., "International Pellet Watch: Global Monitoring of Persistent Organic Pollutants (Pops) in Coastal Waters. 1. Initial Phase Data on Pcbs, Ddts, and Hchs," *Marine Pollution Bulletin* 58, no. 10 (2009); Avio et al., "Pollutants Bioavailability and Toxicological Risk from Microplastics to Marine Mussels," *Environmental Pollution* 198 (2015); Rios et al., "Persistent Organic Pollutants Carried by Synthetic Polymers in the Ocean Environment," *Marine Pollution Bulletin* 54, no. 8 (2007)
[502] Gallo et al., "Marine Litter Plastics and Microplastics and Their Toxic Chemicals Components: The Need for Urgent Preventive Measures,"
[503] Haider et al., "Plastics of the Future? The Impact of Biodegradable Polymers on the Environment and on Society," *Angewandte Chemie-International Edition* 58, no. 1 (2019)
[504] Yeo et al., "Pops Monitoring in Australia and New Zealand Using Plastic Resin Pellets, and International Pellet Watch as a Tool for Education and Raising Public Awareness on Plastic Debris and Pops," *Marine Pollution Bulletin* 101, no. 1 (2015)
[505] Murray E. et al., *National Survey of Pesticides and Emerging Organic Contaminants (Eocs) in Groundwater 2018* (2019)
[506] Gallo et al., "Marine Litter Plastics and Microplastics and Their Toxic Chemicals Components: The Need for Urgent Preventive Measures,"

4.15 We don't fully understand the impacts caused by microplastics

Microplastics are small pieces of plastic less than 5 mm in length, either made that size or degraded from larger plastics. The field of research into the impacts caused by microplastics is in its relative infancy and the evidence is not clear cut. There is a mounting body of evidence that microplastics are present in a very wide range of ecosystems and ingested by a range of organisms, but the physiological implications of this are less certain.

The European Commission's Group of Chief Scientific Advisors articulated this based on the evidence review on the environmental and health risks of microplastic pollution provided by SAPEA (Science Advice for Policy by European Academies):

> "SAPEA (2019) SHOWS THAT THE AVAILABLE SCIENTIFIC KNOWLEDGE ON MICROPLASTIC POLLUTION AND ITS IMPACTS IS A MIX OF CONSENSUS, CONTESTED KNOWLEDGE, INFORMED EXTRAPOLATION, SPECULATION AND MANY UNKNOWNS. THIS REFLECTS BOTH THE IMMATURITY OF THE FIELD AND ITS INTRINSIC COMPLEXITY."[507]

The biggest concerns are that:

- **All ecosystems are at risk.** As well as being pervasive in the marine environment, microplastics are present in freshwater, soil and air, and therefore any identified impacts are likely to be widespread. Beyond the marine ecosystem, the limited but growing body of evidence indicates that microplastics may cause negative impacts for soil and freshwater as well.[508]
- **Species of all sizes are affected.** This occurs through ingesting plastics or via the food chain. A semi-systematic literature review found that marine plastic has a global impact on all ecological subjects reviewed, which included bacteria, algae, zooplankton, invertebrates, fish, turtles, birds and mammals.[509] Most of the impacts of marine plastic pollution were considered irreversible.
- **We don't know the extent to which plants that we eat are taking up microplastics.** There is early evidence that under lab conditions, microplastics accumulate on pores in seed capsules and cause short-term transient effects including delayed germination and root growth,[510] and are taken up by lettuce.[511] A study analysing whether plants took up microplastics when grown in commercial compost that had been used for biodegradable plastics found some evidence for around half of samples tested. These findings were published in a Masters' thesis, but not yet in the peer-reviewed literature.[512] Further research is required to replicate all of these findings.
- **Microplastics may be spread through the environment via wastewater.** A proportion of microplastics are removed in wastewater treatment plants – the extent of removal depends on the level of treatment and type of infrastructure. Those that are retained in the solid fraction could contaminate terrestrial ecosystems if applied as fertiliser or for land rehabilitation, and some remain in the final effluent contaminating aquatic ecosystems,[513] as illustrated in Figure 47.
- **Leachate from poor quality landfill may contain microplastics that leak into the environment.** There is evidence of leachate from landfill containing microplastics in China[514] and Nordic Countries,[515] but this hasn't been studied in Aotearoa New Zealand.

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[507] Group of Chief Scientific Advisors European Comission, "Environmental and Health Risks of Microplastic Pollution", 2019
[508] Lwanga et al., "Incorporation of Microplastics from Litter into Burrows of Lumbricus Terrestris," *Environmental Pollution* 220 (2017); Chae et al., "Current Research Trends on Plastic Pollution and Ecological Impacts on the Soil Ecosystem: A Review," *Environmental Pollution* 240 (2018)
[509] Beaumont et al., "Global Ecological, Social and Economic Impacts of Marine Plastic," *Marine Pollution Bulletin* 142 (2019)
[510] Bosker et al., "Microplastics Accumulate on Pores in Seed Capsule and Delay Germination and Root Growth of the Terrestrial Vascular Plant Lepidium Sativum," *Chemosphere* 226 (2019)
[511] Li et al., "Uptake and Accumulation of Microplastics in an Edible Plant," *Chinese Science Bulletin* 64, no. 0023-074X (2019)
[512] Smith, "Do Microplastic Residuals in Municipal Compost Bioaccumulate in Plant Tissue?" (Royal Roads University, 2018)
[513] Prata, "Microplastics in Wastewater: State of the Knowledge on Sources, Fate and Solutions," *Marine Pollution Bulletin* 129, no. 1 (2018)
[514] He et al., "Municipal Solid Waste (Msw) Landfill: A Source of Microplastics? -Evidence of Microplastics in Landfill Leachate," *Water Research* 159 (2019)
[515] Martijn van Praagh, "Microplastics in Landfill Leachates in the Nordic Countries", 2018

- **We don't understand the risks from current levels in our environment.** Most lab studies use far higher concentrations of plastic that do not reflect those in the natural environment – on the flipside, we may not know the true environmental concentrations due to limit detection of available methods and these high levels may be reached in the future as an increasing amount of plastic accumulates and degrades in the environment.

4.15.1 What this means for Aotearoa New Zealand

Overall, we don't know the extent to which microplastics will impact Aotearoa New Zealand because we don't have a clear understanding of the scale of microplastic pollution at various locations and for different ecosystems, and the impacts of microplastics are still being determined. This was highlighted in a recent review of microplastics risk for Environment Southland by researchers from the Cawthron Institute. [516] This review concluded that 'the risks microplastics pose to ecosystem and human health are not fully characterised and many research and knowledge gaps remain'. Implementing systems to reduce microplastics entering the environment from the known biggest sources can minimise future risk (see Section 4.20.1).

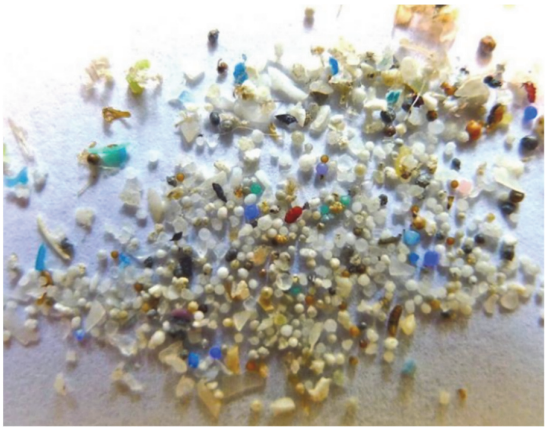


Figure 47 Microplastics – fragments of plastic less than 5 mm in length

Two studies have detected microplastics in the marine environment, one in Christchurch and the other in Auckland (further detail in Section 5.9). For wastewater, early results of a study quantifying microplastics in influent and effluent (but not biosolids) at Christchurch's main wastewater plants shows that microplastics are present and that the different levels of treatment used at each plant removes different amounts of microplastics.[517] These studies are a great starting point but need to be replicated at different sites throughout the country as data cannot necessarily be extrapolated to other regions for a number of reasons including differences in population size, different treatment plant type, and clothing needs for different climates.

Local studies are underway to address some microplastics knowledge gaps for Aotearoa New Zealand through the ESR-led MBIE Endeavour Aotearoa Impacts and Mitigation of Microplastics project, including:

- Microplastics monitoring and education (see Case Study 4.15.3)
- A better understanding of the quantity of microplastics going into wastewater treatment plants (influent) and coming out (effluent), and what's left (biosolids) – considering the effects fragmentation to a size below detection level
- Which stages microplastics leave the liquid phase and/or fragment during the treatment process
- The fate of microplastics used for irrigation/biosolids application and whether they make it to groundwater systems
- The interaction between microplastics and chemical contaminants
- The interaction between microplastics and potential pathogens, soil health and groundwater ecosystem health.

4.15.2 Actions needed to reduce potential risks associated with microplastics

Preliminary local data, global studies highlighting the pervasiveness of microplastics, and the growing body of evidence demonstrating negative impacts on ecosystems, warrant the precautionary principle being applied for microplastics. Preventative measures should be implemented to stop (or remediate) leakage of microplastics into the environment, in concert with focused research to quantify and understand the impact of microplastics in our local setting, particularly on native flora and fauna and taonga species.

[516] Louis A Trembley, "A Review of Microplastics Risk - Implications for Environment Southland", 2019

[517] As only microplastics of >100µm were analysed, these results will not show the full extent of the microplastics present and the reduction seen between those coming in and going out could be a result of fragmentation.

Priority actions include:

- Implementing preventative measures (see Section 4.20.1) or remediation techniques (see Section 4.20.5)
- Building on existing efforts to quantify microplastics in Aotearoa New Zealand across a range of locations and different ecosystems (including marine environment, landfill leachate, wastewater, soil, air) and implementing ongoing monitoring. This also requires developing a more efficient method to process samples, which is currently a bottleneck
- Monitoring international research and undertaking complementary and collaborative research to address knowledge gaps not yet being addressed in local studies (see Section 4.22).

Figure 48 (Over page) Illustration of how microplastics enter and leave the wastewater treatment system. Credit: royalsociety.org.nz/plastics licenced under CC BY 3.0 NZ

MICROPLASTICS IN THE WASTEWATER TREATMENT SYSTEM

Microbeads from industrial cleaning products, industrial abrasives and accidental loss of nurdles

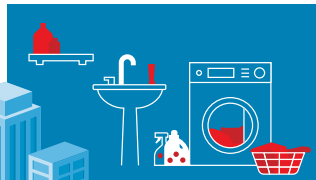
INDUSTRIAL

Fragmented plastic and road abrasions get blown and washed into the waste and stormwater system

STORMWATER

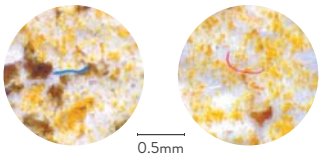
Microbeads and fibres used in personal care products, cleaning products and textiles

RESIDENTIAL



Garments made of synthetic materials, such as polyester and nylon fleece, can release **up to 1900 fibres per wash!**

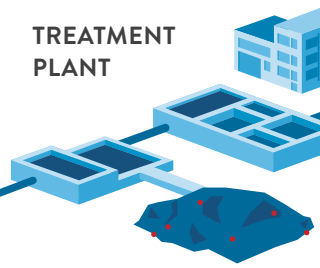
Plastics collected from water leaving a NZ wastewater treatment plant

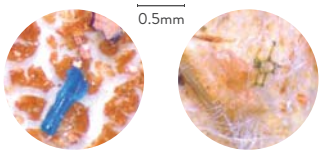


0.5mm

Microplastics washed down drains enter our wastewater treatment plants

TREATMENT PLANT



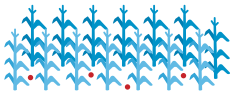


0.5mm

Plastics collected from water entering a NZ wastewater treatment plant

Sewage sludge

Microplastics that are removed during wastewater treatment can end up in sewage sludge that is used as fertilizer in agriculture.



Seep into soil, waterways, and aquifiers

Discharge

Some microplastics are so tiny and light that they do not get removed but leave the plant and enter our waterways and oceans.

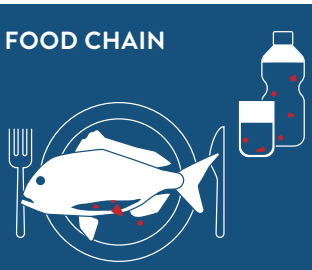
MICROPLASTICS ENTER OUR WATERBODIES

Accumulate in wetlands and streams

Microplastics are ingested by aquatic organisms

ENTERING THE FOOD CHAIN

Microplastics and any toxic chemicals associated with them can end up in our food and drink.



4.15.3 Case study: The Pure Tour

The PURE (Plastic Use Resistance Education) tour was a collaborative project between Massey University, the Algalita Foundation of California, Para Kore, Okeanos and the Los Angeles-5 Gyres Institute. The project was powerful because it connected indigenous science and Western science. Many of the strengths of the project came from te ao Māori guiding principles.

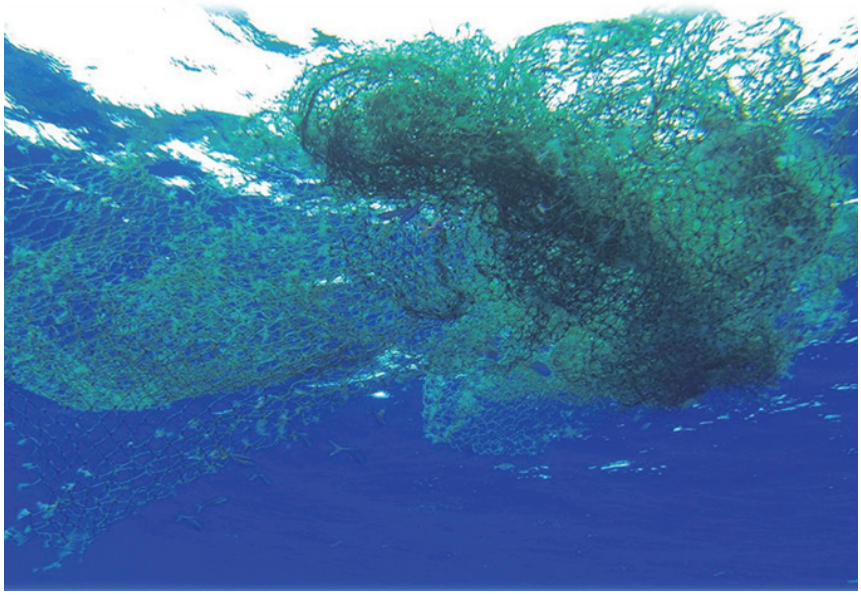


Figure 49 Fish nets lost in the ocean. Photo credit: PURE

Cutting-edge science was performed on board a waka. The team collected plastic debris as they travelled the length of the North Island, quantifying the levels of plastic in our oceans. The data collection expedition translated to meaningful solutions at a community level because it involved stopping into communities to share knowledge about plastic pollution and ways to move towards para kore (zero waste).

The waka was welcomed by the local community, which helped the group engage through citizen science and seminars. As more communities develop knowledge of the problem it helps to start a national conversation about the importance of protecting our environment.

Strong relationships were cemented between the groups and the collaborative nature of the project meant that there was sharing of science disciplines and skills. These foundational relationships have helped the project evolve with the co-design of waka-specific microplastic trawls ready for future expeditions.

Marcus Eriksen from the 5 Gyres Institute wrote about his experience on the PURE tour in an article available at nationalgeographic.com.[518]

[518] Eriksen, "Polynesian Sailing Vessels Are Being Used to Clean up Microplastics", *National Geographic*, 7 June 2018

4.16 We know less about the impact of even smaller plastic particles (nanoplastics)

Less is known about the impacts of smaller plastic fragments (nanoplastics[519]) on organisms, including humans. Research into nanoplastics has only begun recently.[520] Nanoplastics are naturally formed from the degradation from the larger microplastics that are abundant in the environment, as well as being produced in manufacturing of other products. Initial studies imply that nanoplastic is very abundant where microplastic is abundant (up to a billion particles of 100 nm size can be formed from the breakdown of one 5 mm microbead), and can have very long residence times in aquatic environments.[521]

However, there are very few direct measures of the amounts of nanoplastics in the environment, and none currently in Aotearoa New Zealand. It is a particular challenge to measure the amounts, sizes and shapes of these particles because of their small size and composition, and methodological development is required to enable this.

Nanoplastics, in common with other nanoparticles, are of particular concern because they are much more biologically available – able to cross natural biological defence barriers.[522] This gives them longer retention time in plants and animals, and also increases the probability of transfer of surface contaminants into organisms.[523] They are easily inhaled and able to penetrate deeply into the human lung.[524] These particles are very challenging to remediate, as they are smaller than the normal filter sizes used for particle clearing, and require ultrafiltration.[525]

The biggest concerns are that:

- **It is hard to measure nanoplastics.** Measuring the levels in the environment is hindered by issues with isolation, identification and contamination. With current methodological limitations it is difficult to assess the quantity and impacts of particles of this size.
- **It is hard to treat nanoplastics.** Nanoplastics are smaller than normal filters and require ultrafiltration to remove from air or water.
- **The smaller size may mean fragments move into organs more easily.** Early evidence suggests that the smaller size may help these fragments pass through membranes and be transported into organs. Inhalation is a greater issue than for larger particles.
- **Nanoplastics may have a longer retention time than microplastics.** Once ingested, nanoplastics may cross cell membranes and enter the bloodstream and organs, resulting in a longer retention time in the body than larger microplastics.

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[519] Nanoplastics are plastic fragments smaller than 1µm in at least one dimension. ISO/TS 80004-1:2015 (https://www.iso.org/standard/68058.html)
[520] Wagner et al., "Things We Know and Don't Know About Nanoplastic in the Environment," *Nature Nanotechnology* 14, no. 4 (2019)
[521] Brandon et al., "Long-Term Aging and Degradation of Microplastic Particles: Comparing in Situ Oceanic and Experimental Weathering Patterns," *Marine Pollution Bulletin* 110, no. 1 (2016)
[522] Brennecke et al., "Ingested Microplastics (>100 Mm) Are Translocated to Organs of the Tropical Fiddler Crab *Uca Rapax*," *Marine Pollution Bulletin* 96, no. 1-2 (2015); Ward et al., "Marine Aggregates Facilitate Ingestion of Nanoparticles by Suspension-Feeding Bivalves," *Marine Environmental Research* 68, no. 3 (2009); Santana et al., "Microplastic Contamination in Natural Mussel Beds from a Brazilian Urbanized Coastal Region: Rapid Evaluation through Bioassessment," *Marine Pollution Bulletin* 106, no. 1-2 (2016); Farrell et al., "Trophic Level Transfer of Microplastic: Mytilus Edulis (L.) to Carcinus Maenas (L.)," *Environmental Pollution* 177 (2013); Koehler et al., "Effects of Nanoparticles in *Mytilus Edulis* Gills and Hepatopancreas: A New Threat to Marine Life?," *Marine Environmental Research* 66, no. 1 (2008); Browne et al., "Ingested Microscopic Plastic Translocates to the Circulatory System of the Mussel, Mytilus Edulis (L.)," *Environmental Science & Technology* 42, no. 13 (2008); Sussarellu et al., "Oyster Reproduction Is Affected by Exposure to Polystyrene Microplastics,"
[523] Santana et al., "Microplastic Contamination in Natural Mussel Beds from a Brazilian Urbanized Coastal Region: Rapid Evaluation through Bioassessment,"; Farrell et al., "Trophic Level Transfer of Microplastic: Mytilus Edulis (L.) to Carcinus Maenas (L.),"; Ward et al., "Separating the Grain from the Chaff: Particle Selection in Suspension- and Deposit-Feeding Bivalves," *Journal of Experimental Marine Biology and Ecology* 300, no. 1-2 (2004)
[524] Xing et al., "The Impact of Pm2.5 on the Human Respiratory System," *Journal of Thoracic Disease* 8, no. 1 (2016)
[525] Ultrafiltration refers to the range of technologies for removing particles less than 100 nm in size. These technologies typically involve high pressure, and are very susceptible to membrane fouling, reducing their efficiency.

- **The principles of trophic transfer apply.**[526] Smaller particles can be ingested and accumulate up the food chain in the same way as microplastics. They may also be able to be taken up through other routes such as across gills of fish[527] or through endocytosis by plants.[528]

WE CAN'T YET ASSESS THE RISKS ASSOCIATED WITH NANOPLASTICS. THIS NEEDS TO BE A FOCUS OF FUTURE RESEARCH

4.16.1 What this means for Aotearoa New Zealand

Like microplastics, there is the potential for negative impacts associated with these plastic particles to affect our native flora and fauna, taonga species and human health. Because the field of research is new, there is little local evidence. However, the mobility of nanoplastics into tissues provides the potential that they may transfer to the edible tissues of organisms.[529]

4.16.2 Actions needed to address potential risks of nanoplastics

Even though the body of evidence is far smaller, the precautionary principle should apply to smaller plastic particles as well. Methodological improvements are a priority to ensure that nanoplastics can be quantified in the environmental setting, and once this is achieved ongoing microplastic monitoring efforts (as recommended above) should incorporate nanoplastics. Source prevention and remediation efforts should also factor in the far smaller fragment size of nanoplastics.

[526] Toussaint et al., "Review of Micro- and Nanoplastic Contamination in the Food Chain," *Food Additives and Contaminants Part a-Chemistry Analysis Control Exposure & Risk Assessment* 36, no. 5 (2019); Chae et al., "Current Research Trends on Plastic Pollution and Ecological Impacts on the Soil Ecosystem: A Review,"; Murray et al., "Plastic Contamination in the Decapod Crustacean *Nephrops Norvegicus* (Linnaeus, 1758)," *Marine Pollution Bulletin* 62, no. 6 (2011); Santana et al., "Microplastic Contamination in Natural Mussel Beds from a Brazilian Urbanized Coastal Region: Rapid Evaluation through Bioassessment,"; Mattsson et al., "Brain Damage and Behavioural Disorders in Fish Induced by Plastic Nanoparticles Delivered through the Food Chain," *Scientific Reports* 7, no. 1 (2017)

[527] Al-Sid-Cheikh et al., "Uptake, Whole-Body Distribution, and Depuration of Nanoplastics by the Scallop Pecten Maximus at Environmentally Realistic Concentrations," *Environmental Science & Technology* 52, no. 24 (2018)

[528] Bosker et al., "Microplastics Accumulate on Pores in Seed Capsule and Delay Germination and Root Growth of the Terrestrial Vascular Plant Lepidium Sativum,"

[529] Chae et al., "Current Research Trends on Plastic Pollution and Ecological Impacts on the Soil Ecosystem: A Review," Farrell et al., "Trophic Level Transfer of Microplastic: Mytilus Edulis (L.) to Carcinus Maenas (L.)," Mattsson et al., "Brain Damage and Behavioural Disorders in Fish Induced by Plastic Nanoparticles Delivered through the Food Chain,"

4.17 Plastic pollution poses a biosecurity risk

If lost in the ocean, plastic can travel a huge distance over a long amount of time. This was illustrated by the journeys of more than 28,000 rubber ducks lost at sea in a shipping container en route from China to Seattle in 1992 – the ducks washed up across beaches over a decade later far away from where they were lost.[530]

Figure 50 Rubber ducks lost at sea helped researchers track ocean currents of debris

The buoyancy and strength of plastic make it an ideal raft to transport species over large distances, over long periods of time. These features of plastic mean it can facilitate travel into areas species previously wouldn't have been able to get to, through water, soil or air. There is evidence of invasive species travelling via larger plastic objects[531] and microbes travelling via microplastics.[532]

The biggest concerns are:

- **Plastic pollution may help spread pathogens and invasive species.** Plastic debris provides a unique environment that allows complex communities, including pathogens, to survive and travel where they may not normally.[533]
- **Ingestion of plastics colonised with microbes may spread pathogens further.** Ingestion of plastics by marine animals can also facilitate transmission of pathogens to other animals in the same species through close contact, and bridge the gap between ecosystems.[534]
- **New or invasive microbial species have the potential to alter whole ecosystems.** Introduction of new microbes via plastics may cause significant changes in existing microbial communities and could potentially alter ecosystem function and processes such as nutrient cycling.[535]
- **Rafting of organisms poses a threat to global biodiversity.** The incidence of anthropogenic debris has more than doubled the rafting opportunities for organisms and therefore poses a significant threat to global biodiversity.[536]

[530] Fisher, "How Lego Figures and Rubber Ducks Reveal Ocean Secrets", *BBC*, 22 July 2014
[531] Derraik, "The Pollution of the Marine Environment by Plastic Debris: A Review," *Marine Pollution Bulletin* 44 (2002); Gregory, "Environmental Implications of Plastic Debris in Marine Settings-Entanglement, Ingestion, Smothering, Hangers-on, Hitch-Hiking and Alien Invasions," *Philosophical Transactions of the Royal Society B-Biological Sciences* 364, no. 1526 (2009)
[532] Oberbeckmann et al., "Spatial and Seasonal Variation in Diversity and Structure of Microbial Biofilms on Marine Plastics in Northern European Waters," *Fems Microbiology Ecology* 90, no. 2 (2014); Faury et al., "*Vibrio Crassostreae* Sp Nov., Isolated from the Haemolymph of Oysters (*Crassostrea Gigas*)," *International Journal of Systematic and Evolutionary Microbiology* 54 (2004)
[533] Eich et al., "Biofilm and Diatom Succession on Polyethylene (Pe) and Biodegradable Plastic Bags in Two Marine Habitats: Early Signs of Degradation in the Pelagic and Benthic Zone?," *Plos One* 10, no. 9 (2015); Lobelle et al., "Early Microbial Biofilm Formation on Marine Plastic Debris," *Marine Pollution Bulletin* 62, no. 1 (2011); Wright et al., "Microplastic Ingestion Decreases Energy Reserves in Marine Worms," *Current Biology* 23, no. 23 (2013); Keswani et al., "Microbial Hitchhikers on Marine Plastic Debris: Human Exposure Risks at Bathing Waters and Beach Environments," *Marine Environmental Research* 118 (2016)
[534] Bolch et al., "A Review of the Molecular Evidence for Ballast Water Introduction of the Toxic Dinoflagellates *Gymnodinium Catenatum* and the *Alexandrium* "Tamarensis Complex" to Australasia," *Harmful Algae* 6, no. 4 (2007); Gregory, "Environmental Implications of Plastic Debris in Marine Settings-Entanglement, Ingestion, Smothering, Hangers-on, Hitch-Hiking and Alien Invasions,"; Rochman et al., "Ingested Plastic Transfers Hazardous Chemicals to Fish and Induces Hepatic Stress,".
[535] Amaral-Zettler et al., "The Biogeography of the Plastisphere: Implications for Policy," *Frontiers in Ecology and the Environment* 13, no. 10 (2015); Oberbeckmann et al., "Spatial and Seasonal Variation in Diversity and Structure of Microbial Biofilms on Marine Plastics in Northern European Waters,"; Goldstein et al., "Increased Oceanic Microplastic Debris Enhances Oviposition in an Endemic Pelagic Insect," *Biology Letters* 8, no. 5 (2012).
[536] Barnes, "Biodiversity: Invasions by Marine Life on Plastic Debris," *Nature* 416, no. 6883 (2002)

4.17.1 What this means for Aotearoa New Zealand

Exotic plant and animal pests that hitchhike on plastic in the sea could threaten Aotearoa New Zealand's biosecurity. A study of 27 beaches along the Coromandel Peninsula found that plastic debris poses a high risk of transfer for both native species and non-indigenous marine species, creating a biosecurity risk.[537] The main culprit for carrying bio-fouling taxa, particularly biosecurity pests, was rope debris used in fisheries and aquaculture. Further studies are needed, but this early evidence suggests that better management of plastics used in marine environments could reduce biosecurity risks.

4.17.2 Actions needed to reduce biosecurity risk related to plastic

The ultimate action that will reduce the risks associated with plastic pollution is to minimise plastic litter. In conjunction with this, research needs to address knowledge gaps not yet being addressed in local studies (see Appendix 6), including studies to better understand what poses a threat to Aotearoa New Zealand biosecurity through plastics. The ESR-led MBIE Endeavour Aotearoa Impacts and Mitigation of Microplastics project is partly addressing this by looking at species that pose a biosecurity risk (invasive species or pathogens).

4.18 Plastics may contribute to antimicrobial resistance

The microbes that colonise microplastics may be human and animal pathogens. The influence of microplastics on microbiological health risks is a growing area of research. There is emerging evidence that the biofilm environment established by microbes on microplastics is one that can support the spread of antimicrobial resistance, if it also attracts antibiotics or other chemicals that select for resistance.[538] Antimicrobial resistance is considered an imminent threat to Aotearoa New Zealand.[539] Our understanding about the risks of microplastic-associated antimicrobial resistance is currently very limited and we don't yet know the extent to which plastics may facilitate antimicrobial resistance and what downstream risks that poses for this global health issue. The potential for plastic pollution to contribute to this risk needs to be better understood through local research as well as monitoring findings from international research efforts.

[537] Campbell et al., "Aquaculture and Urban Marine Structures Facilitate Native and Non-Indigenous Species Transfer through Generation and Accumulation of Marine Debris," *Marine Pollution Bulletin* 123, no. 1 (2017)

[538] By bringing together bacteria, conjugative plasmids and chemicals that select for resistance, microplastics may be an accelerant for antibiotic resistance evolution. Kirstein et al., "Dangerous Hitchhikers? Evidence for Potentially Pathogenic Vibrio Spp. On Microplastic Particles," *Marine Environmental Research* 120 (2016); Arias-Andres et al., "Microplastic Pollution Increases Gene Exchange in Aquatic Ecosystems," *Environmental Pollution* 237 (2018); Kurenbach et al., "Herbicide Ingredients Change Salmonella Enterica Sv. Typhimurium and Escherichia Coli Antibiotic Responses," *Microbiology-Sgm* 163, no. 12 (2017); Eckert et al., "Microplastics Increase Impact of Treated Wastewater on Freshwater Microbial Community," *Environmental Pollution* 234 (2018)

[539] Office of the Prime Minister's Chief Science Advisor, "Antimicrobial Resistance – an Imminent Threat to Aotearoa, New Zealand", 2018

4.19 Plastic may impact human health and wellbeing

A comprehensive report on the risks to human health caused by plastic, led by CIEL, provides a detailed overview of the health impacts associated with plastic particles and associated chemicals at every stage of its supply chain and life cycle.[540]

In brief, the risks outlined include:

- **Extraction and transport:** Potential carcinogenic, neurotoxic and disruptive effects to the reproductive and immune systems from the chemicals used to produce the main feedstocks for plastic, putting industry workers at risk.
- **Refining and manufacture:** Potential carcinogenic and toxic effects from the chemicals used to transform fossil fuel into plastic resin and additives. Because these are airborne, industry workers and neighbouring communities are particularly at risk.
- **Consumer use:** Potential carcinogenic, developmental or endocrine disrupting impacts from exposure via ingestion or inhalation with plastics that have certain chemical additives or contaminants.
- **Plastic waste management:** Different processes may release various toxic substances to the air, water and soils to those working in the industry or living nearby. This depends on the waste management approach and the chemical contaminants on the plastic.
- **Plastic in the environment:** People may be exposed via microplastics in the environment or through the food chain. The risks from chemical contaminants increase as the plastic degrades.

The World Health Organization (WHO) examined the evidence related to the occurrence of microplastics in the water cycle, the potential health impacts from microplastic exposure, and the removal of microplastics during wastewater and drinking-water treatment.[541]

The WHO concluded:

- Microplastics are ubiquitous in the environment and have been detected in a broad range of concentrations in marine water, wastewater, fresh water, food, air and drinking-water (bottled and tap). **The data on the occurrence of microplastics in drinking-water are limited at present, with few fully reliable studies using different methods and tools to sample and analyse microplastic particles.**
- The potential hazards associated with microplastics come in three forms: physical particles, chemicals and microbial pathogens as part of biofilms. Based on the limited evidence available, **chemicals and biofilms associated with microplastics in drinking-water pose a low concern for human health.** Although there is insufficient information to draw firm conclusions on the toxicity related to the physical hazard of plastic particles, particularly for the nano size particles.
- Limited evidence suggests that key sources of microplastic pollution in fresh water sources are terrestrial run-off and wastewater effluent. However, **optimised wastewater (and drinking-water) treatment can effectively remove most microplastics from the effluent.** For the significant proportion of the population that is not covered by adequate sewage treatment, microbial pathogens and other chemicals will currently be a greater human health concern than microplastics.

The biggest concerns about plastics and human health are:

- **We don't know how much plastic humans ingest or inhale,** beyond a few estimates and comparisons. Precise data to assess the exact exposure of humans to micro- and nanoplastics via diet cannot be produced until standardised methods and definitions are available.[542] A recent high profile study by researchers at the University of Newcastle estimated that an average person could be ingesting approximately 5 grams of plastic every week – the equivalent

[540] Center for International Environmental Law, "Plastic & Health: The Hidden Costs of a Plastic Planet", 2019
[541] World Health Organization, "Microplastics in Drinking-Water", 2019
[542] Toussaint et al., "Review of Micro- and Nanoplastic Contamination in the Food Chain," *Food Additives & Contaminants: Part A* 36, no. 5 (2019)

of one credit card.[543] Sources of ingestion identified in the study included drinking water, shellfish, beer and salt. This study did not include data from Aotearoa New Zealand. Another recent study found that certain fancy teabags release billions of microparticles.[544]

- **We don't understand the short- and long-term risks of exposure**. Uncertainties and knowledge gaps mean that we aren't able to fully evaluate the human health impacts of plastic. The evidence is difficult to assess and findings are contested. The Netherlands Organisation for Health Research and Development has funded 15 short-term projects as part of a Microplastics and Health programme. Interim results were shared at a summit in October 2019, but final results are not due until mid-2020 and funding has been granted to extend these projects.[545]
- **The consequences to human health from plastics transferred through the food chain are unclear**.[546] Seafood has been identified as a potential route of microplastics and associated chemical pollutants into the human diet, with a growing body of literature demonstrating the presence of nano- and microplastics in commonly eaten marine species, such as mussels, oysters, fish, sea cucumbers and lobsters. Further investigation is required.[547]

4.19.1 What this means for Aotearoa New Zealand

Plastic is imported to Aotearoa New Zealand as resin or manufactured plastic materials, so our local population is not affected by the potential risks outlined above for the extraction, transport, refining and synthesis of the constituent compounds as well as the manufacture of the finished resins. Potential risks of those stages of the plastics life cycle should be factored in with any new approaches to onshore production and manufacture of plastics, including bio-plastics.

Our understanding of how much plastic and the different types of plastic people in Aotearoa New Zealand are exposed to through consumer use, waste management and environmental exposure is very limited (discussed further Chapter 5). This information is a prerequisite to being able to identify risks to human health. With current evidence we cannot determine the risk that plastic poses to the health for people in Aotearoa New Zealand.

A few studies have quantified the levels of plastic in local food sources:

- A study quantified microplastics in table salt, but limited results did not allow for determination of the potential dietary intake[548]
- Research from the University of Auckland's Institute of Marine Science identified that 33 out of 34 commercial fish species had evidence of ingested plastic across four locations in the South Pacific, including Auckland. The maximum ingestion rate was recorded in a New Zealand species, *Kyphosidae* or *Parore*, as well as in yellowfin tuna from Rapa Nui. Out of the eight most common species specific to Aotearoa New Zealand, only one did not ingest plastics.[549] Note that plastics in the gut of fish would not be ingested by humans, but plastic or chemical contaminants in tissues could be.

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[543] Cox et al., "Human Consumption of Microplastics," *Environmental Science & Technology* 53, no. 12 (2019)
[544] Hernandez et al., "Plastic Teabags Release Billions of Microparticles and Nanoparticles into Tea," *Environmental Science & Technology* (2019)
[545] More information available at: https://www.zonmw.nl/en/research-and-results/life-sciences-health/programmas/programme-detail/microplastics-health/
[546] Law et al., "Microplastics in the Seas," *Science* 345, no. 6193 (2014)
[547] Avio et al., "Pollutants Bioavailability and Toxicological Risk from Microplastics to Marine Mussels,"; Browne et al., "Ingested Microscopic Plastic Translocates to the Circulatory System of the Mussel, Mytilus Edulis (L.),"; Cannon et al., "Plastic Ingestion by Fish in the Southern Hemisphere: A Baseline Study and Review of Methods," *Marine Pollution Bulletin* 107, no. 1 (2016); Dehaut et al., "Microplastics in Seafood: Benchmark Protocol for Their Extraction and Characterization," *Environmental Pollution* 215 (2016); Graham et al., "Deposit- and Suspension-Feeding Sea Cucumbers (Echinodermata) Ingest Plastic Fragments," *Journal of Experimental Marine Biology and Ecology* 368, no. 1 (2009); Murray et al., "Plastic Contamination in the Decapod Crustacean *Nephrops Norvegicus* (Linnaeus, 1758),"; Santana et al., "Microplastic Contamination in Natural Mussel Beds from a Brazilian Urbanized Coastal Region: Rapid Evaluation through Bioassessment,"; Van Cauwenberghe et al., "Microplastics in Bivalves Cultured for Human Consumption," *Environmental Pollution* 193 (2014); Rochman et al., "Anthropogenic Debris in Seafood: Plastic Debris and Fibers from Textiles in Fish and Bivalves Sold for Human Consumption," *Scientific Reports* 5 (2015)
[548] Karami et al., "The Presence of Microplastics in Commercial Salts from Different Countries," *Scientific Reports* 7 (2017)
[549] Markic et al., "Double Trouble in the South Pacific Subtropical Gyre: Increased Plastic Ingestion by Fish in the Oceanic Accumulation Zone," *Marine Pollution Bulletin* 136 (2018)

More studies to quantify the levels of plastic in local food sources are required, particularly for shellfish because people eat the whole animal. A study is underway at the University of Auckland investigating microplastics in Aotearoa New Zealand food and beverages.

Though data are limited, we can estimate exposure through food sources using existing evidence as a starting point. For example, the yearly consumption of different mollusc species in Aotearoa New Zealand is around 440 g per capita per year.[550] Using the average microplastic load detected in mollusc species, the dietary exposure to microplastic through mollusc consumption can be around 924 and 4620 microplastic fragments per capita per year. However, the estimate for microplastic loads in shellfish in Aotearoa New Zealand is highly uncertain as there are currently limited data available for the levels of microplastics in shellfish grown in Aotearoa New Zealand waters, highlighting the need for greater assessment of the current level of contamination within food. This was partly addressed in a local study that quantified microplastics in green-lipped mussels from around Aotearoa New Zealand, which found zero to 1.5 particles in mussels at six out of nine locations tested.[551] This initial study noted that it is likely that the methods used underestimated the levels. Ingestion of plastics through seafood and seabirds may be of particular concern for tangata whenua.

We can also look beyond the potential health risks associated with ingestion through marine food sources and determine how else people are exposed to microplastics in Aotearoa New Zealand and what health risks may be associated with this exposure. Recent evidence suggests that groundwater has the potential to become contaminated by the land disposal of wastewater effluent and biosolids, and horticultural plastics. This is of particular concern for Aotearoa New Zealand as we rely heavily on groundwater as a source of drinking water. Some knowledge gaps for this will be addressed by a new study by the Ministry for Primary Industries, New Zealand Food Safety. This project will analyse the dietary exposure of microplastics, absorption rates of plastics and their contaminants through the human gut, impact of cooking/food prep on the microplastics and their contaminants and influence on absorption/risk.

There is also evidence that plastic litter on beaches may cause injury. A local study determined that anthropogenic beach litter, including plastic, poses a common and pervasive exposure hazard to all ages, with a specific risk to young children.[552] Plastic litter may further impact wellbeing through changes to food provisions, livelihoods and income, especially in coastal communities.[553] Cultures that are closely linked to the ocean and environment and particularly vulnerable to these changes.[554] For Māori, this may be expressed through the mauri of a resource being negatively impacted. Existing environmental assessment tools and frameworks that observe the mauri of a specific environment may be helpful to track the impact of plastic on certain environments (outlined in Appendix 7).

[550] Peter Cressey, "Risk Profile: Ciguatoxins in Seafood", 2019
[551] Webb et al., "Microplastics in the New Zealand Green Lipped Mussel Perna Canaliculus," *Marine Pollution Bulletin* 149 (2019)
[552] Campbell et al., "Are Our Beaches Safe? Quantifying the Human Health Impact of Anthropogenic Beach Litter on People in New Zealand," *Science of The Total Environment* 651 (2019)
[553] Naeem et al., "Biodiversity and Human Well-Being: An Essential Link for Sustainable Development," *Proceedings of the Royal Society B: Biological Sciences* 283, no. 1844 (2016)
[554] Beaumont et al., "Global Ecological, Social and Economic Impacts of Marine Plastic,"

4.19.2 Actions needed to reduce health risk to humans

Despite significant knowledge gaps, the available evidence around the pervasiveness of plastics in the environment suggests a precautionary approach is appropriate. This could include monitoring levels of plastics in food and drinks (following international best practice e.g. the European project 'ECsafeSEAFOOD')[555] and filtering small particles from water.

4.20 Ways to prevent and reduce the impacts of plastic pollution

Preventing and reducing the impacts of plastic pollution requires a multipronged approach that includes reducing the use of plastics overall (see Chapter 2), prioritising the redesign of products that may end up in the environment at end-of-life so that they have the least environmental impact if this is their fate (see Chapter 3), preventing leakage at source (see Section 4.20.1), remediating existing pollution (see Section 4.20.5), and sector-specific approaches to mitigate economic impacts (see Section 4.21). Effective, systemic and enduring mitigation of this environmental harm requires measurement and monitoring tools not yet developed in Aotearoa New Zealand, and only unevenly applied in other countries.

4.20.1 Focus on prevention at source

Preventing leakage of any litter into the environment to avoid the impacts on wildlife and ecosystems is challenging with today's infrastructure and consumption habits, and we know that a considerable amount of plastic that is produced worldwide ends up polluting our environment. The Ocean Conservancy published a report 'Stemming the Tide: Land-based strategies for a plastic-free ocean' which details a series of solutions that could help to prevent leakage of plastic from land into the oceans – specifically focused on viable opportunities that exist today.[556]

Knowing how and where plastic enters the environment is fundamental to preventing (or reducing) any associated impacts. There have been global efforts to broadly quantify the sources of plastic pollution – such as the estimate that 80% of marine-based plastic comes from land[557] – and the main mechanisms are generally well understood, as illustrated in Figure 51. The ultimate goal should be to prevent all leakage of plastic into the environment. In order to do this, we need a complete understanding of the mechanisms through which plastic enters the environment in Aotearoa New Zealand. We currently don't know the sources, routes, how much and which types of plastic enter the environment in Aotearoa New Zealand. That information is critical to prioritise efforts to reduce environmental leakage at source and is described further in Chapter 5.

Here we present several case studies that demonstrate failure in Aotearoa New Zealand's systems that lead to plastics entering the environment. These case studies highlight where we should start to prevent environmental leakage of plastic, while better data are captured to inform priorities and solutions to address the whole system of plastic pollution.

Figure 51 (Over page) Sources and pathways of plastic pollution that ends up in the marine environment. Credit: royalsociety.org.nz/plastics licenced under CC BY 3.0 NZ

[555] Part of the FP7 Programme (Cooperation, Food, Agriculture and Fisheries, and Biotechnology in Europe, which includes 18 partners from 10 European countries, and focuses on the health risk from seafood in relation to priority contaminants including microplastics. See: http://www.ecsafeseafood.eu

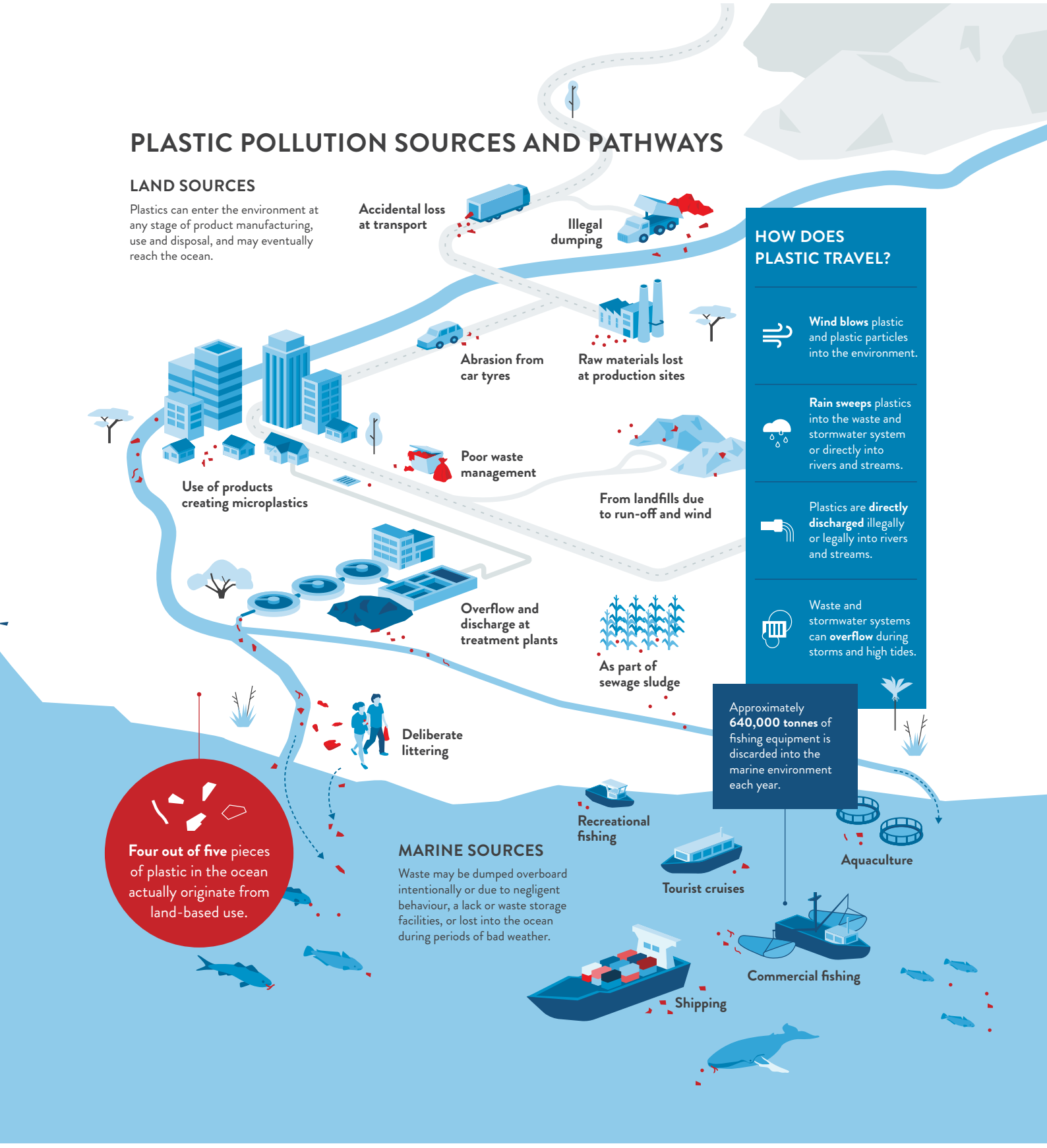
[556] Ocean Conservancy, "Stemming the Tide: Land-Based Strategies for a Plastic- Free Ocean", 2017

[557] Li et al., "Plastic Waste in the Marine Environment: A Review of Sources, Occurrence and Effects,"

PLASTIC POLLUTION SOURCES AND PATHWAYS

LAND SOURCES

Plastics can enter the environment at any stage of product manufacturing, use and disposal, and may eventually reach the ocean.



HOW DOES PLASTIC TRAVEL?

Wind blows plastic and plastic particles into the environment.

Rain sweeps plastics into the waste and stormwater system or directly into rivers and streams.

Plastics are **directly discharged** illegally or legally into rivers and streams.

Waste and stormwater systems can **overflow** during storms and high tides.

Approximately **640,000 tonnes** of fishing equipment is discarded into the marine environment each year.

MARINE SOURCES

Waste may be dumped overboard intentionally or due to negligent behaviour, a lack or waste storage facilities, or lost into the ocean during periods of bad weather.

4.20.2 Case study: Compromised landfills at risk during extreme weather

In March 2019, a storm hit the West Coast and washed out the closed Fox River landfill near Fox Glacier. The result was that huge amounts of pollution leaked into the surrounding pristine natural environment. Volunteers and specialist teams began clean-up efforts immediately, led by the local council. After several weeks, the Department of Conservation took over the clean-up, working with members of the Defence Force and hundreds of volunteers. Recovery faced delays due to resourcing and funding issues. An estimated 135,000 kilograms of rubbish was retrieved over 21 kilometres of river and 64 kilometres of coastline. It filled over 11,000 rubbish bags.

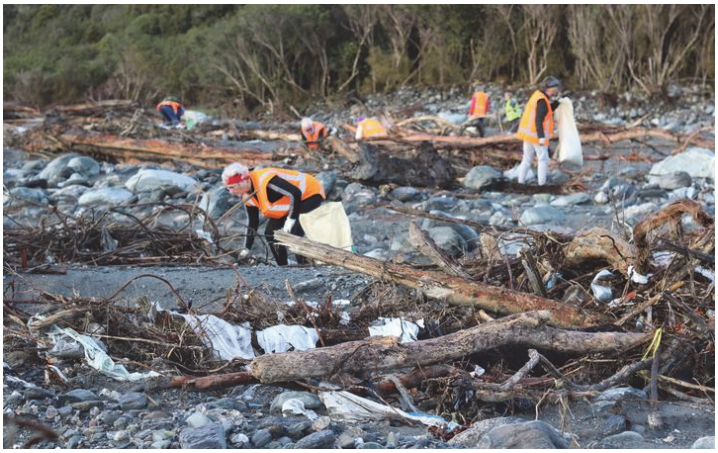


Figure 52 Volunteers pick up rubbish where a disused Fox River landfill spilled litter on the West Coast. Photo Credit: RNZ

AN ESTIMATED 135,000 KILOGRAMS OF RUBBISH WAS RETRIEVED OVER 21 KILOMETRES OF RIVER AND 64 KILOMETRES OF COASTLINE

This landfill disaster demonstrated that Aotearoa New Zealand's existing landfills are a potential source of plastic leakage into the environment. Those at most risk of this kind of event are the decommissioned landfills established with less stringent regulatory requirements, many of which were established near rivers and coastlines and are particularly vulnerable to storms or flooding. Approximately 100 landfills around the country are compromised or going to be in the near future and an audit of the risks associated with current and closed landfills is underway.[558] This rate may go up with more severe weather patterns emerging.[559]

AOTEAROA NEW ZEALAND'S EXISTING LANDFILLS ARE A POTENTIAL SOURCE OF PLASTIC LEAKAGE INTO THE ENVIRONMENT

Taking a preventative approach to remediate at-risk landfills, rather than a reactive approach to a landfill disaster, is critical for reducing environmental leakage of plastic and other waste. This will include efforts to remediate problematic landfills or stabilise and prevent those at risk, funds ready to support local and central government to act, and established systems so that the burden of clean-up doesn't rest on volunteers.

Just because waste is 'out of sight' in a landfill doesn't mean it has necessarily reached its end-of-life. Waste in landfill, including plastic, still has the potential to enter environments when the landfill is mismanaged. In the long-term, the goal is to stop landfilling plastic waste. Until then, waste plastic should only be landfilled in modern landfill under strict regulatory conditions (see Case Study 3.8.1).

[558] New Zealand Government, "Minister Announces Multi-Agency Landfill Risk Response", press release, 11 September 2019, https://www.scoop.co.nz/stories/PA1909/S00075/minister-announces-multi-agency-landfill-risk-response.htm
[559] Local Government NZ, "Vulnerable: The Quantum of Local Government Infrastructure Exposed to Sea Level Rise", 2019

4.20.3 Case study: The road to reducing microplastics from tyres

Numerous studies have identified tyre abrasion as the leading cause of microplastics emissions into the environment, far outweighing other sources such as manufacturing resin, washing of synthetic clothing, and fishing gear.[560] Globally, it is estimated that tyres leak around 1.5 million tonnes of microplastics each year.[561] Because of the currently limited opportunities to capture microplastics from tyres, these are also predicted to be the largest source of microplastics entering the aquatic environment.

TYRE ABRASION IS THE LEADING CAUSE OF MICROPLASTICS EMISSIONS INTO THE ENVIRONMENT, FAR OUTWEIGHING OTHER SOURCES SUCH AS MANUFACTURING RESIN, WASHING OF SYNTHETIC CLOTHING, AND FISHING GEAR

In a report prepared for the European Commission, Eunomia estimated the cost-effectiveness of different methods to prevent microplastics from tyres entering the environment.[562]

The study considered:

1) Development of a standard measure of tyre tread abrasion rate as a pre-requisite to
   a) Including tyre tread abrasion rates on the tyre label to inform consumer choices, or
   b) Using regulation for tyre tread abrasion to restrict the worst performing types from the market.

The study concluded that restricting certain types of tyres from the market alone, or in combination with labelling measures, were relatively cost-effective ways to prevent emissions at source. However, estimates suggested that even the most effective measure would at most reduce microplastics from tyres reaching surface water by 33%. Further capture systems would be needed to prevent tyre microplastics entering waterways, but the costs of this were not estimated in this study.

The findings from this study could be used to prioritise policy measures that will reduce microplastics from tyres entering the environment in Aotearoa New Zealand.

[560] Ryberg et al., "Global Environmental Losses of Plastics across Their Value Chains," *Resources, Conservation and Recycling* 151 (2019) Sutton, "Understanding Microplastic Levels, Pathways, and Transport in the San Francisco Bay Region", 2019
[561] Ryberg et al., "Global Environmental Losses of Plastics across Their Value Chains,"
[562] Eunomia Research & Consulting Ltd, "Investigating Options for Reducing Releases in the Aquatic Environment of Microplastics Emitted by Products", 2018

4.20.4 Case study: Microplastics from our clothing

Scion's study of microparticles in waterways in the Auckland region identified 87% of microparticles were fibres.[563] Our clothing is a major source of microplastic pollution and we need effective measures to prevent leakage at source. The leakage occurs when we wear and wash synthetic clothing, such as anything made from polyester, acrylic or nylon, as tiny synthetic microfibres shed from the clothing and enter the waterways when the dirty water is flushed out of the machine. This is worse for more water-intense cycles such as delicate wash.[564]

Possible solutions to prevent textiles being a source of microplastics include:

- **Refuse synthetic textiles and embellishments:** The most effective prevention is to not use them in the first place. Replacing synthetic materials such as polyester, nylon and acrylic with natural alternatives such as wool, cotton and linen will not always be a viable option, but when it is this solution prevents microfibres entering the environment. Avoiding plastic embellishments such as sequin and glitter will also reduce leakage.
- **Engineer and manufacture better performing textiles:** Where synthetic textiles are needed, following good practice design principles and treatment methods that reduce the amount of fibre shedding as much as possible should be taken.[565] This includes using longer fibre length and twist, lower yarn count, higher density, and reduced abrasion against other fibres, as well as investigating finishing treatments that prevent shedding.[566] By preventing the fibres from shedding in the first place, these approaches are much more effective than capturing once in water. A self-certification process to govern the implementation of a maximum threshold for fibre release was determined to be a cost-effective approach to reducing textile-sourced microplastics.[567]
- **Stopping fibres from leaving the washing machine:** In the instances where fabric does shed microfibres, remediation measures need to be taken to capture the fibres from water and prevent them entering the marine environment. There are washing bags and filters that can be applied at home or in industrial settings to catch microplastic fibres before they enter wastewater. Several companies are now selling these filters and these can drastically reduce the amount entering the waterways, though none stop 100% of fibres. This approach relies on individuals taking measures to implement filters on their washing machines and dispose of the fibres appropriately. One way to ensure these measures are more widespread is to start incorporating filters into washing machines in the manufacturing stage.[568] Such a move has been announced by a Turkish manufacturer of washing machines.[569]
- **Improve filtering processes at wastewater treatment plants:** Fibres that leave the washing machine end up in the wastewater treatment plant. Without appropriate filtering infrastructure these fibres will enter waterways as part of the effluent. Where filtering is able to capture some or all of the fibres, these will become part of the solid waste. Current wastewater treatments are not effective at filtering out microplastics and depending on the age of the system, may require upgrades before appropriate filtering infrastructure can be added to the system.

[563] Kate Parker, "Turning the Tide on Plastic Microparticles", 2019
[564] Kelly et al., "Importance of Water-Volume on the Release of Microplastic Fibers from Laundry,"
[565] Mermaids Ocean Clean Wash, "Handbook for Zero Microplastics from Textiles and Laundry", 2019
[566] De Falco et al., "Pectin Based Finishing to Mitigate the Impact of Microplastics Released by Polyamide Fabrics," *Carbohydrate Polymers* 198 (2018)
[567] Eunomia Research & Consulting Ltd, "Investigating Options for Reducing Releases in the Aquatic Environment of Microplastics Emitted by Products", 2018
[568] More information available at: https://www.macpac.co.nz/, https://planetcare.org/en/ and https://www.oceancleanwash.org
[569] More information available at: https://www.ecotextile.com

4.20.5 Remediate existing plastic pollution

Stopping plastic pollution at source is critical to reduce the impact of plastic on the environment, but even if we stopped any further plastic from entering the environment today, there will still be an enormous volume of plastic in our oceans. Larger, visible plastic items will continue to degrade into smaller plastic particles that become less visible and less easy to remove. Efforts to remove plastic debris are warranted and there are numerous efforts around the world to remove larger bits of plastic debris from the land and oceans. For example, the US NOAA marine debris program supports many different removal projects, mostly through funding locally driven community initiatives.[570] In Aotearoa New Zealand, several NGO groups are dedicated to removing plastic debris from the ocean or coastlines, including Sea Cleaners and Sustainable Coastlines, while others retrieve litter before it makes its way into our waterways (discussed further in Section 2.6).

Figure 53 The LittaTrap in place to prevent plastic and other litter entering the waterways through the drainage system

LARGER, VISIBLE PLASTIC ITEMS WILL CONTINUE TO DEGRADE INTO SMALLER PLASTIC PARTICLES THAT BECOME LESS VISIBLE AND LESS EASY TO REMOVE

Though removing some marine plastic is possible, it is time intensive, expensive and inefficient. More efficient and cost-effective remediation techniques for larger ocean plastics will be crucial to reduce the impact of plastic in the environment. Recent reports indicate that an ocean clean-up device was able to successfully retrieve plastic from an ocean gyre for the first time during a trial, with plans to now scale-up and improve the device.[571]

For microplastics or smaller particles, there are no remediation methods currently available that could quickly, efficiently and safely remove these from the environment. This area of research should be watched closely to see what opportunities could be scaled-up. Before scaling, it is important that rigorous testing is done to prevent unintended consequences. For example, we need to be sure that the remediation technique doesn't harm small organisms in the environment at the same time. Some initial studies have shown potential on a small scale using methods such as:

- Bioremediation (using microrganisms) to remove microplastics[572]
- Decomposing and mineralising microplastics using nanosprings[573]
- Removing microplastics from water using liquids known as ferrofluids.[574]

Already some products have been developed to reduce the amount of litter that enters the oceans and waterways, by intercepting litter from land before it enters stormwater drains, such as the LittaTrap.[575] Continued research into techniques that safely and effectively remove or intercept plastic from the environment, including small particles, is necessary.

[570] More information available at: https://marinedebris.noaa.gov/current-efforts/removal
[571] Boffey, "Ocean Cleanup Device Successfully Collects Plastic for First Time", *The Guardian*, 3 October 2019
[572] Paço et al., "Biodegradation of Polyethylene Microplastics by the Marine Fungus Zalerion Maritimum," *Science of The Total Environment* 586 (2017)
[573] Kang et al., "Degradation of Cosmetic Microplastics Via Functionalized Carbon Nanosprings," *Matter* (2019)
[574] More information available at: https://www.googlesciencefair.com/projects/2018/2c3f6207b15f46cb4bb66a56095bd6d901ccfa42e7e51600c766df7856590c4e
[575] More information available at: https://www.stormwater360.co.nz/products/stormwater-management/gross-pollutant-traps/prod/LittaTrap-

4.21 Mitigate potential economic impacts

Most analyses to quantify the economic impacts of plastic pollution have focused on ocean plastics. The currently available evidence for the ecological, social and economic impacts of marine plastic was synthesised in a recent review.[576] In that study, the global estimate of the economic impact of marine plastic was around $2.5 trillion each year. A detailed analysis of the local economic implications of plastic pollution are outside of the scope of this report. However, this is an important area that requires further research and consideration. The presence of plastic in the marine environment has a significant impact on the economy of a country in several different ways. The key ways are through changes to:

- **Tourism:** Larger plastics and plastic fragments, which are easily seen with the naked eye, can affect the aesthetics of the coastal zone. As plastics are a very clear visual indicator of human pollution their presence may directly impact a country's tourism industry by affecting the image of having clean, pristine environments. This can therefore have an impact on the country's reputation and consequently the number of visitors they will get. It will also affect the perceived value of a place and therefore the monetary value as a destination.
- **Fisheries:** Microplastics may have a multifaceted impact on fisheries-based economies in both the short and long term. Their direct impact on animal health and reproduction may affect fisheries stocks and/or the health of the ecosystem on which they rely. For example, larval fish may starve due to preferential feeding on microbeads, resulting in a crash in the population, and a knock-on effect on higher trophic levels. Pathogens may be transported to areas that have previously been geographically isolated, but are now accessible due to the long-range movement of plastic fragments.
- **Export industry:** Fisheries exports may be hindered by the contamination of seafood. Although more research is required to determine the level of risk to human health through the consumption of plastic-contaminated seafood, the evidence that already exists gives cause for concern. Should a health risk be demonstrated, legislation for microplastics and nanoplastics as contaminants in food, similar to those currently in place for other forms of contamination such as microbes and chemicals, may be implemented by importing countries. However, the lack of evidence does not necessarily negate the potential negative impact on the seafood industry that the presence of plastic may have. The public's perception of the purity of the seafood may have a deleterious effect on its own.

[576] Beaumont et al., "Global Ecological, Social and Economic Impacts of Marine Plastic,"

4.21.1 What this means for Aotearoa New Zealand

The economic risks of plastic pollution may be of greatest concern to countries who market their seafood as 'pure' and grown in the wilderness away from the impacts of human activity and for those who rely heavily upon their seafood export industry. This makes Aotearoa New Zealand particularly vulnerable to the economic implications associated with plastic in the marine environment. Our NZ$1.48 billion per year wild-capture fishery (estimate for 2018) is at risk from microplastic pollution. These impacts are likely to become more pronounced as plastic pollution accumulates and degrades into smaller pieces that will be more accessible to species lower down the food chain. Some see this as a 'ticking time bomb' for our aquaculture and fisheries industries.

Our tourism and agricultural industries could also be at risk. A study by the Ministry for Primary Industries determined that with Aotearoa New Zealand's worldwide reputation for high quality wine, any changes due to microplastics in the soil resulting from the accumulation of millions of discarded netting clips over years and decades could affect this NZ$1.61 billion export industry.[577] Further work currently underway by the Ministry for Primary Industries aims to better assess the potential trade/socio-economic impacts of plastic pollution for our country. The global increase in plastic pollution also brings with it opportunities. It is likely that there will be a market for food and seafood that is 'plastic' free.

The knowledge gaps around scale and impact of plastic pollution in our local context make it difficult to fully understand the potential economic implications on Aotearoa New Zealand. Economic analyses should be undertaken to model the impacts of plastic pollution on different sectors, including aquaculture, fisheries, agriculture/horticulture, exports and tourism.

4.22 Knowledge gaps

There are significant knowledge gaps around the impacts of plastic on the environment, which can be broadly grouped as:

- The sources, quantities, routes and fate of macro-, micro- and nanoplastics in Aotearoa New Zealand, specifically focused on marine, freshwater and terrestrial environments, and wastewater
- The impacts and risks of plastic on biodiversity and ecosystems, particularly for taonga species
- The impacts on health, including quantities of microplastics in food and drink sources in Aotearoa New Zealand and whether mana whenua may particularly be exposed to an increased dietary loading compared to the general population through recreational and customary harvest of wild foods
- The characteristics and levels of chemical additives and contaminants associated with plastics in Aotearoa New Zealand and their impacts, including the degree of transfer and accumulation between levels of the food chain
- The levels and types of plastics in all landfills (current and decommissioned) and the risk of leaks to the environment through natural disaster, particularly in relation to climate change (changes in rainfall levels, storm frequency and intensity, sea level etc.), and through leachate
- The downstream impacts on the economy.

[577] Ministry for Primary Industries, "Situation and Outlook for Primary Industries.", 2017

4.23 Summary and recommendations

There are impacts on the environment throughout the whole life cycle of a plastic product, with particularly significant impacts if leaked into the environment. There is still a lot we don't know about the environmental and health impacts related to plastic. Research is required to address these knowledge gaps. Efforts to understand the risk to our local communities and taonga are essential, alongside international collaborative efforts to study impacts and align to international best practice. Without changing how we use and dispose of plastic, the environmental consequences are expected to be stark. It is critical to act now to protect the environment by using plastic in a sustainable and responsible way. This is addressed through the series of recommendations within recommendation 6.

Key considerations for implementing these recommendations:

- Mana whenua should be supported to be involved in environmental monitoring aspects of plastics.
- Ensure that research is connected to international research communities and prioritises filling local knowledge gaps.
- Ensure that measures to reduce environmental impacts of plastic align to international pacts, pledges and data collection framework, including:
  - UNSDGs[578]
  - Basel Convention[579]
  - GESAMP ocean plastic monitoring guidelines.[580]
- Draw on local ongoing efforts related to plastic in the environment, including
  - Sustainable Coastlines (see Case Study 5.9.4)[581]
  - Local research (see Appendix 6)
  - Operation Clean Sweep® (see Case Study 2.4.11).[582]

[578] UN General Assembly, "Transforming Our World: The 2030 Agenda for Sustainable Development September 25, 2015", 2016
[579] The amendment to the Basel Convention to restrict waste plastic being shipped from developed to developing countries was signed by 187 countries and will begin to be enforced in 2020. Holden, "Nearly All Countries Agree to Stem Flow of Plastic Waste into Poor Nations", *The Guardian*, 11 May 2019
[580] The Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection have developed a set of publically available guidelines for monitoring plastics and microplastics in the oceans, further detail available at: http://www.gesamp.org/news/how-to-monitor-plastics-in-the-oceans
[581] Further details about Sustainable Coastlines, including data collection methodology are available at: http://sustainablecoastlines.org/
[582] More information about the Operation Clean Sweep® initiative in New Zealand is available at: http://www.plastics.org.nz/environment/marine-litter/operation-clean-sweep

5. To what extent can we quantify Aotearoa's plastic? New Zealand's data challenge

"WE LACK A FULL NATIONAL PICTURE OF WHAT IS GOING TO LANDFILL, AND WHAT IS BEING RECOVERED OR RECYCLED. KNOWING THIS IS CRITICAL IF WE ARE TO MAKE INFORMED DECISIONS"
MINISTER EUGENIE SAGE, GREEN PARTY AGM, AUGUST 2018

In this chapter, we draw on publicly accessible data to attempt to quantify plastic flows through Aotearoa New Zealand. We highlight knowledge gaps and what data are needed to inform plastics action across the country.

5.1 A snapshot of plastic in Aotearoa New Zealand

Measuring the amount and types of plastic we use and discard is a prerequisite for appropriate management and monitoring – it is a vital step in allowing us to make evidence-informed decisions around where we direct resources to improve our use and management of plastic, and to track their effectiveness. A baseline material flow analysis is essential to inform and prioritise policy changes and to hold us accountable by measuring improvements over time. We need to understand the scale of plastic use and the types of plastic that are most problematic to inform what changes to implement and their relative priorities. It is necessary not only to consider which plastics are used most often, but also how long the products are used for and whether appropriate end-of-life solutions are available.

There is currently no coordinated or standardised approach to measure or report plastic use and disposal by material type in Aotearoa New Zealand. As a result, there are large gaps in our understanding of the material flows of plastic through the country. Throughout our consultations with various stakeholders along the plastics value chain, the need for accurate and thorough data collection has been unanimously cited as a priority area. With the Ministry for the Environment and numerous businesses signing the New Plastics Economy Global Commitment,[583] it is a critical time to initiate the collection of high-quality data on plastics so that we have a solid understanding of the baseline from which we must improve and to inform practical and meaningful decisions in the short-term.

Our analysis has identified how plastics flow through Aotearoa New Zealand, and where data are or should be captured. The data we report here were obtained from existing databases or published reports. Where data were not available or only partially representative of the national use of plastics, case studies were used. Given the variety of sources and methods, there were varying levels of confidence in the estimates. The findings are detailed in this chapter and summarised in Figure 54 and Table 24. By collating currently accessible data on the amount and types of plastic used and discarded in Aotearoa New Zealand, we have highlighed major gaps in our understanding of plastic material flow through the country, underpinned by the lack of a framework to report plastic use and disposal by material type.

IT IS A CRITICAL TIME TO INITIATE THE COLLECTION OF HIGH-QUALITY DATA ON PLASTICS SO THAT WE HAVE A SOLID UNDERSTANDING OF THE BASELINE FROM WHICH WE MUST IMPROVE

[583] Hon Eugenie Sage, "New Zealand Signs Global Declaration to Cut Plastic Waste,"

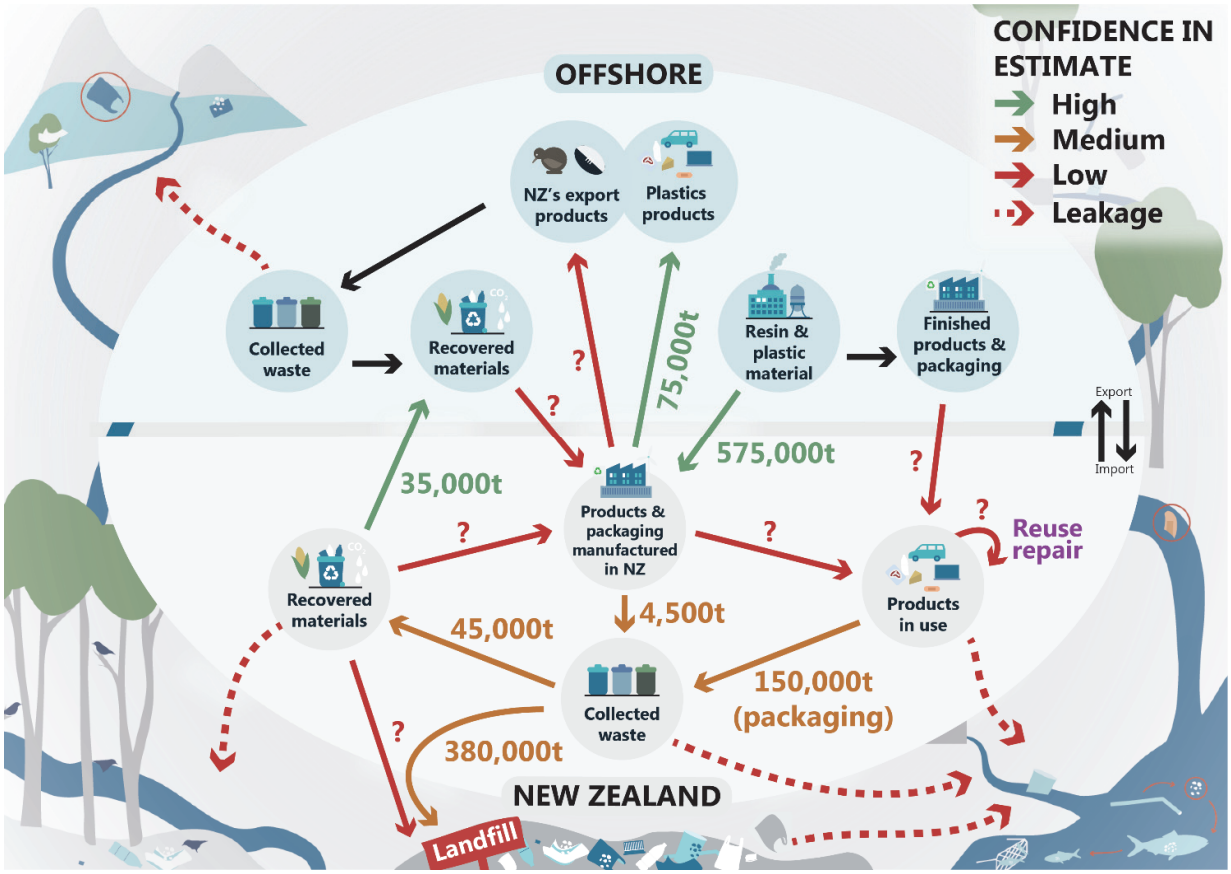


Figure 54 Flows of plastic into and out of Aotearoa New Zealand, including leakage into the environment. Plastic leaking into the environment includes macro and microplastics, and affects land, marine and air environments. It also includes waste that is burned or buried in unregulated landfill. Sources of data are outlined in Table 24.

Table 24 Summary of what we know about the amount of plastic in Aotearoa New Zealand

		Tonnes/ year	Confidence	Source (year)	Partial data
IMPORT	Raw resin and plastic material	575,000	High	Statistics NZ (2018)[584]	
	Finished products or packaged goods	?	?		Synthetic textiles – 13,000 tonnes (see Case Study 5.2.3)
EXPORT	Raw resin and plastic material	75,000	High	Statistics NZ (2018)	
	Finished products or packaged goods	?	?		
	Waste plastic	35,000	High	Statistics NZ (2018)	
IN USE	Packaging	150,000	Medium	Packaging NZ (2015)[585]	Plastic drink bottles – 25,000 tonnes (see Case Study 5.5.4)
	Construction	?	?		350 m^2 residential development – 80 kg mixed plastic waste (see Case Study 5.7.11)
	Agriculture	?	?		Waikato and BOP rural properties – 5900 tonnes wraps, covers, films; 1500 tonnes containers, drums (see Case Study 5.7.10)
	Other	?	?		
WASTE	Plastic collected for recycling	45,000	Medium	NRRT[586] (2018)	
	Plastic waste landfilled	380,000	Medium	Eunomia (2015) and Perrot et al. (2018)[587]	
	Pre-consumer industrial waste	4,500	Medium~	Plastics NZ (2005)[588]	
LEAKED INTO ENVIRONMENT	Marine litter	?	?		Sustainable Coastlines – average litter density of 411/1,000 m^2 [589]
	Land litter	?	?		Keep New Zealand Beautiful – average litter density 118/1,000 m^2 [590]

[584] Harmonised trade data from Statistics NZ Infoshare
[585] Estimates based on export waste and population/GDP data, not accounting for imported finished products, packaged goods, secondary and tertiary packaging
[586] National Resource Recovery Taskforce estimates based on voluntary reporting
[587] Conservative estimate for landfills based on data for class 1 landfills: 12% (Perrot et al. 2018) by tonnes (Eunomia Consulting)
[588] Based on voluntary manufacturer surveys from 2005
[589] Taken from litterintelligence.org as of 11 November 2019
[590] Keep New Zealand Beautiful, "National Litter Audit", 2019

5.2 How much plastic do we import?

In Aotearoa New Zealand, plastic is imported as resin which is then manufactured into products and packaging, or imported as part of a finished product and/or packaging. To gain a complete understanding of the amount and types of plastic entering the country, we need to be able to capture metrics for both the resin and finished products.

5.2.1 Imports of raw resin and plastic products

Tonnages of imported plastic material

Currently, the weight (and $NZD value) of raw resin imports and some plastic products are captured under trade commodity 39, 'Plastics and articles thereof', within the Harmonised Trade System.[591] The data are obtained from export and import entry documents lodged with the New Zealand Customs Service, and provided via Statistics NZ.[592]

Imports have increased from around 400,000 to 575,000 tonnes in the past 10 years (see Figure 55), with an associated increase in value of $845 million. Of the amount imported, over half is identified as 'in primary forms' (including resins) and the remainder are products, many of which are used in manufacturing such as plates, sheets, film, foil and strip. Some other plastic products are captured in these imports, but it is not exhaustive. The total weight of imports in primary form have increased since 2009, but the proportion of resin versus other products has decreased from 63% in 2009 to 53% in 2019 (See Appendix 8 for detail).

IN 2018, AROUND 575,000 TONNES OF PLASTIC RESIN AND PRODUCTS WERE IMPORTED TO AOTEAROA NEW ZEALAND

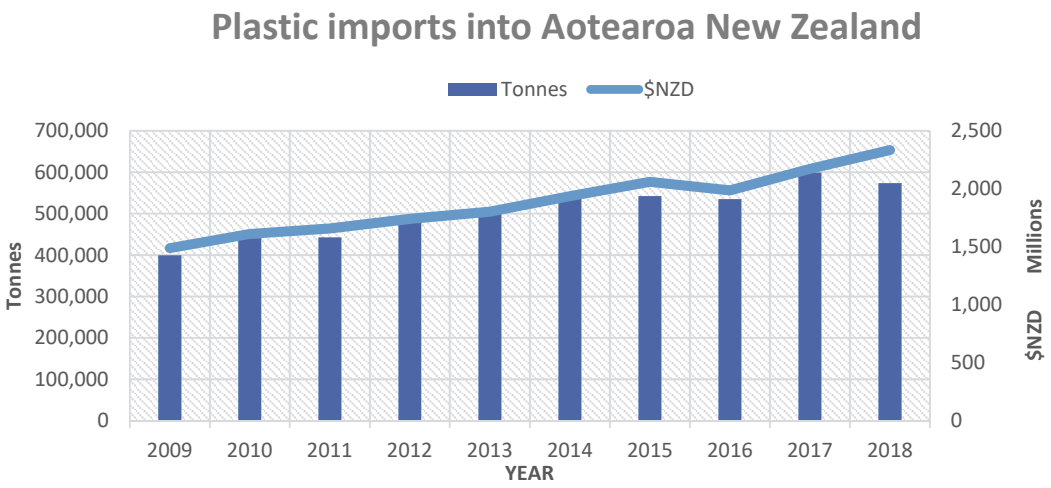


Figure 55 Plastic imports captured by 'plastics and articles thereof' by tonnes and $NZD for the past 10 years.

[591] Details of the New Zealand Harmonised System Classification 2017 (NZHSC) available at: http://archive.stats.govt.nz/methods/classifications-and-standards/classification-related-stats-standards/harmonised-system-2017.aspx.
[592] Data from Harmonised Trade data from Statistics NZ Infoshare available at: http://archive.stats.govt.nz/infoshare/

Types of plastic imported

The type of plastic that a product is made out of essentially dictates the best outcome for what happens at its end-of-life. Therefore, to invest in the right technology and infrastructure so that we can manage our own plastic waste onshore, we need to understand the proportion and amount of each type of plastic imported and ensure that the technology and infrastructure is flexible enough to deal with changes in plastic volumes and types. The breakdown of material types imported as raw resin can be used as a starting point, but because this does not capture the material type of all plastic imported as finished products or packaging, it is limited in its accuracy. In addition, raw resins may be combined with other resins or materials and this may limit end-of-life options for the products manufactured from these.

Import data for resin types 1-7 shows that LDPE (#4) is the most common type of plastic imported in raw resin form (see Table 25) (see Appendix 8 for details of specific trade codes included in this analysis). The proportions of each resin are roughly in line with global estimates for plastic use.

Table 25 Breakdown of resin types 1-7 imported into Aotearoa New Zealand in 2018 in raw resin form

Type	% of plastic in NZ	% from global estimates[593]
1 (PET)	7	<10
2 (HDPE)	26	*with LDPE 36
3 (PVC)	12	12
4 (LDPE)	31	*
5 (PP)	18	21%
6 (PS)	4	<10
7 (other)	3	<10

[593] Geyer et al., "Production, Use, and Fate of All Plastics Ever Made,"

Between 2009 and 2018, the volume of raw resin imported into Aotearoa New Zealand has fluctuated, particularly for HDPE (#2) (see Figure 56). There has been a steady increase in the tonnes of imported LDPE (#4), which is used for products such as soft plastic packaging and bale. The tonnes of imported PP (#5) has also increased – this type of plastic is recyclable but is often limited by the infrastructure to do so and also the ability of recyclers to separate it out as a sorted waste stream. There appears to be a sharp dropoff in the tonnes of PS (#6) imported. The reason for this is unknown and could be due to changes in trade coding or supplier exemption to report as the weight for expansible polystyrene dropped from over 10,000 tonnes to zero in one year.

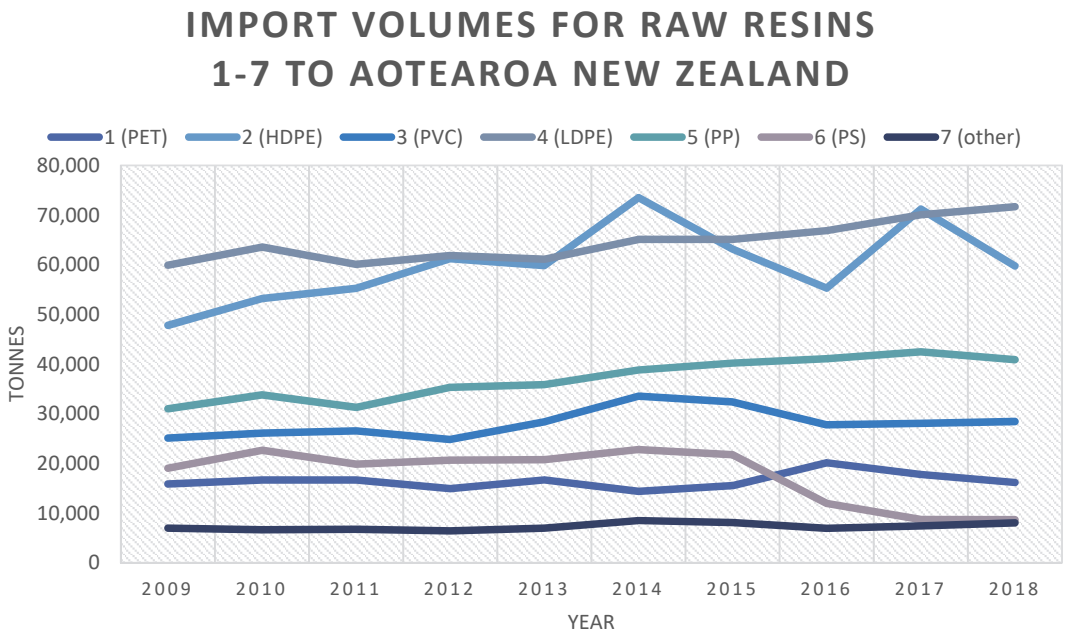


Figure 56 Tonnes of raw resin (types 1-7) imported into Aotearoa New Zealand from 2009 to 2018

Sources of imported plastics

Plastic resin and products captured by trade data under 'Plastics and articles thereof' are mainly imported from Asia, Australia and North America (see Figure 57).[594] The volumes of imports by economy in Figure 57 do not distinguish between bio- and fossil-based plastics. Negligible amounts of bioplastic are manufactured onshore for research purposes, but not for production, and are ignored for the current snapshot. On the other hand, for imported finished products made of or containing plastics these data do not illustrate which countries are the biggest suppliers (excluding the few products captured by the trade data).

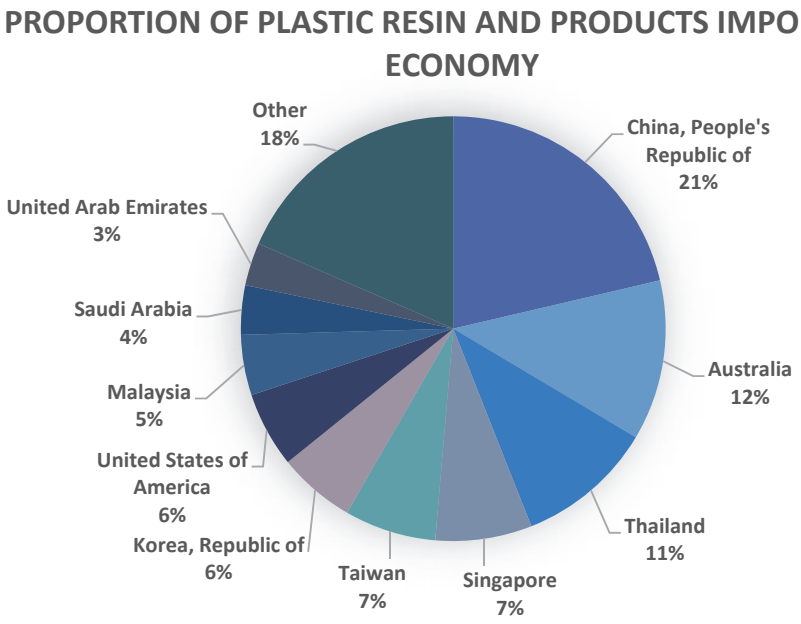


Figure 57 Proportion of resin and plastic product imports captured by trade data for 2018, by economy of origin

[594] Data from Harmonised Trade data from Statistics NZ Infoshare available at: http://archive.stats.govt.nz/infoshare/

5.2.2 Knowledge gaps

Plastics in finished products or packaged goods

Import data do not currently capture the volume of all plastic entering the country within finished products or packaged goods. Finished products may be completely or partly made of plastic, but these data are not necessarily captured within the categorisation 'Plastics and articles thereof'. This is because a finished product is often not defined by what it is made from.

Examples of finished products that contain plastic but are not included under the category 'Plastics and articles thereof' in import data include toys, appliances, clothing and footwear, electronics, food and beverages (packaging), teabags, cars, tyes, cigarettes, building materials and medical products.

The total weight and types of plastic that are imported into Aotearoa New Zealand in finished products and/or associated packaging is unknown. Rough estimates could be made by calculating approximate quantities of plastic per product and multiplying this by the number of those products that are imported via Statistics NZ data.[595] Further, secondary and tertiary plastic packaging is used throughout different stages of the supply chain and is also not captured in import data. An example of this is stretch film used to wrap pallets.

Hard to capture plastics

Even after considering both imported raw resin and finished products, we are likely to still be missing some plastic entering the country for two main reasons. Firstly, some products have 'hidden' plastics – it may not be obvious that there is plastic in the product at all. For example, an aluminium can of drink is actually lined with a plastic resin and the base ingredient of chewing gum is a type of plastic. However, hidden products are unlikely to account for a large proportion of plastic imported into Aotearoa New Zealand. Other data simply may not be captured, including consignments valued under $1,000, which will include individual products purchased online and received via international shipping and the packaging around imported products. [596] Again, this is likely to be relatively small in volume although increasing with the popularity of internet shopping.

[595] Data from Harmonised Trade data from Statistics NZ Infoshare available at: http://archive.stats.govt.nz/infoshare/

[596] According to Statistics NZ, consignments valued under $1000 are excluded from trade statistics for import into or export from New Zealand; see http://datainfoplus.stats.govt.nz.

5.2.3 Case study: How big is the plastic clothing problem for Aotearoa New Zealand?

Some plastic articles of clothing are captured in the 'Plastics and articles thereof' harmonised trade codes in import data from Statistics NZ, but this does not account for all synthetic fibres imported into the country. Drawing on data from the 'Apparels' and 'Textiles' harmonised trade codes captured in import data from Statistics NZ, we estimated the weight of synthetic textiles imported into Aotearoa New Zealand as finished products (Figure 58).[597]Tonnages of apparels defined as 'of synthetic fibres', 'of artificial fibres' and 'of man-made fibres' and textiles defined as 'of nylon or other polyamides', 'of polyester' or those coated or laminated with plastics were included (see Appendix 9 for a list of all codes included in this analysis). Note that man-made fibres may include viscose rayon and other non-synthetic fibres, so this is potentially an over-estimate.

IN 2018, AN ESTIMATED 13,000 TONNES OF SYNTHETIC TEXTILES WERE IMPORTED TO AOTEAROA NEW ZEALAND.

Figure 58 Estimated tonnes of synthetic textiles imported into Aotearoa New Zealand not captured as plastic imports

[597] Data from Harmonised Trade data from Statistics NZ Infoshare available at: http://archive.stats.govt.nz/infoshare/

5.3 What do we manufacture from imported plastic?

We assume the amount of resin imported into Aotearoa New Zealand is manufactured into plastic products and/or packaging materials onshore (see Section 5.2). Understanding the material type, lifetime use and sector use of manufactured products is essential for informing decisions around managing plastic waste and directing efforts for redesign of products manufactured in Aotearoa New Zealand.

Plastics manufacturers have detailed data on their use of polymers and products produced and disposed. Previously, this information has been collected and aggregated by Plastics NZ via surveys, with the last survey completed in 2012. Based on the results of the 2012 survey, Plastics NZ estimated that over half of the imported resin was manufactured into packaging, with the remainder mainly used in construction and agriculture (see Figure 59). Of the material manufactured into packaging, 60% was used for rigid packaging and the remaining 40% was used for flexible packaging.

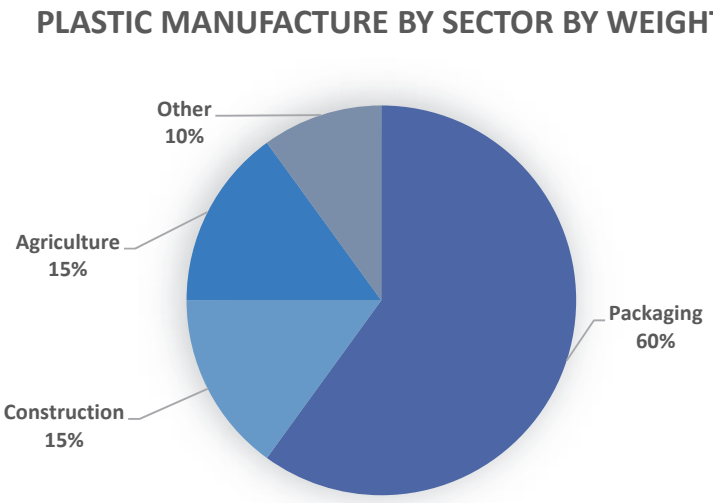


Figure 59 Plastics NZ estimates of the proportion of imported resin used for manufacture by sector

For comparison, estimates for sector use of resin plastics calculated from data for Europe, the United States, China and India covering the period 2002–2014 are 44.8% packaging, 18.8% construction, 11.9% consumer and institutional products, 6.7% transportation, 3.8% electrical, 0.8% industrial machinery, and 13.2% other.[598]

AROUND 60% OF THE RESIN IMPORTED INTO AOTEAROA NEW ZEALAND IS MANUFACTURED INTO PACKAGING, WHICH IS DOMINATED BY SINGLE-USE OR SHORT-LIVED PRODUCTS

[598] Geyer et al., "Production, Use, and Fate of All Plastics Ever Made,".

The estimates made by Plastics NZ are derived from survey data which was then extrapolated based on import data from Statistics NZ. Plastics NZ stopped collecting mass balance surveys after 2012, due to limitations in data availability (reporting was voluntary and dropped off when the Packaging Accord finished in 2009) and concerns around accuracy of these data and the number of assumptions needing to be made to perform estimates.

As a result, there are no recent, accurate data on the products and packaging manufactured in Aotearoa New Zealand from imported resin.

Specifically, we lack clarity on:

- The amount of each polymer type used for manufacture, by sector
- Key product uses, by sector
- How long products are used for (short-term vs long-term).

Some companies are making the weight of plastic packaging they produce publically available, as part of their participation in the New Plastics Economy Global Commitment.[599] This includes some Aotearoa New Zealand owned and operated companies, such as Earthwise Group Ltd, who stated that they produce 284 tonnes of plastic packaging per year.

[599] Ellen MacArthur Foundation, "The New Plastics Economy Global Commitment ", 2017

5.4 How much plastic do we export?

There are little data on how much plastic is exported from Aotearoa New Zealand. Data are collected on items identified as 'Plastics and articles thereof' but not on other products that may include plastic. Furthermore, Aotearoa New Zealand's export industry relies heavily on plastic packaging. Examples of some of the exported products that may use plastic packaging include dairy, meat, fruit and vegetables, seafood and honey.

Detailed data on tonnage and $NZD value of exports is available from Customs New Zealand via Statistics NZ.[600] As with imports, plastic resin and some products are captured under the harmonised trade code 39 'Plastics and articles thereof' (see Appendix 10). Waste plastic exports are captured in these data but not included in this analysis (see Section 5.7.4). For articles captured in trade data, export tonnages have fluctuated between 2009 and 2018, with an overall increase from roughly 60,000 to 75,000 tonnes and an associated increase in value of $79 million (see Figure 60).

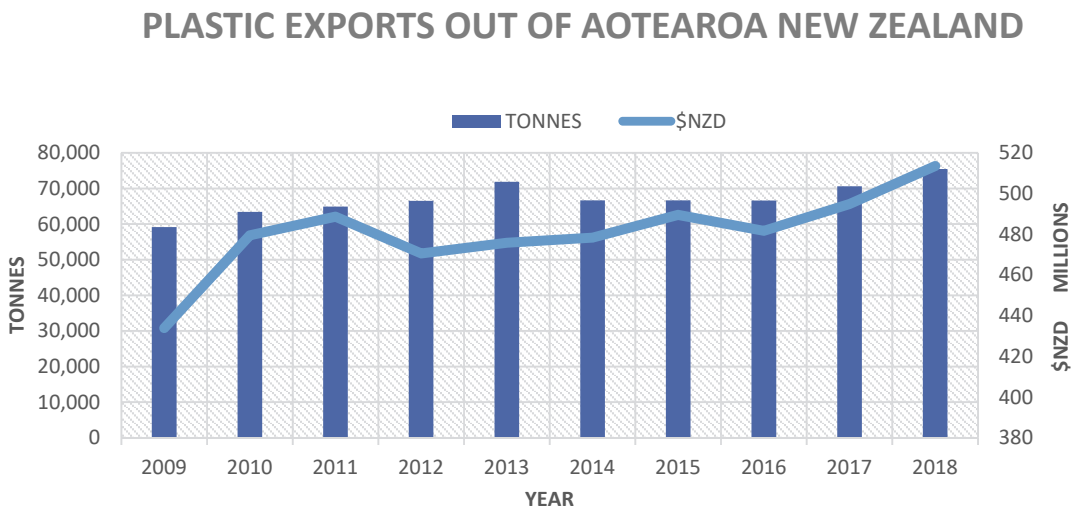


Figure 60 Plastic exports captured by 'plastics and articles thereof' by tonnes and $NZD for the past 10 years, excluding plastic waste

Tonnage and $NZD value is available for all other exported products, including finished products and packaged goods that contain plastic, but the weight or type of plastic within these is not recorded. The same method used to estimate plastic use in imported finished products (see Case Study 5.2.3), could be used to estimate the amount of plastic exported in all exported products.

[600] Data from Harmonised Trade data from Statistics NZ Infoshare available at: http://archive.stats.govt.nz/infoshare/

5.5 How much plastic is in use in Aotearoa New Zealand?

Global estimates have considered the volumes of plastic 'in use' and how this differs by sector (see Figure 61).[601] It is estimated that 30% of plastics ever produced are currently in use. Entering and leaving the 'in use' phase differs significantly by sector. In 2015, 146 million tonnes of plastic entering use were for packaging, and 141 million tonnes left the use phase, whereas 65 million tonnes entered use for construction and only 12 million tonnes left use. PVC (#3), a dominant material type used for pipes in construction, had over double the weight enter the use phase compared to the amount that left the use phase (38 vs 16 million tonnes).

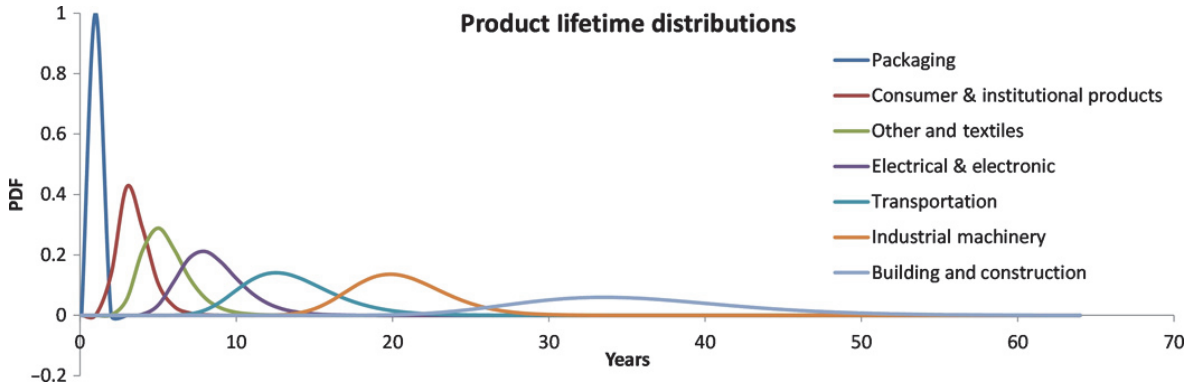


Figure 61 Differences in product lifetime distributions for plastics in different sectors highlight that packaging has the biggest volume and shortest length of use. Product lifetime is plotted as log-normal probability distribution functions (PDF). Source: Geyer et al. 2017.

Understanding which types and how much plastic is in use, and when it is likely to leave the use phase, is important for waste management planning. We also need more information about the nature and quantity of plastic use in Aotearoa New Zealand in order to increase resource efficiency and appropriately reuse, refurbish, remanufacture, repair, recycle or dispose of plastic products in Aotearoa New Zealand's economy.

[601] Geyer et al., "Production, Use, and Fate of All Plastics Ever Made,"

5.5.1 Packaging mass balance estimates

The closest estimates to establishing the volume of plastic in use in Aotearoa New Zealand are the packaging mass balance results published as part of the Packaging Accord from 2004 to 2009,[602] and – in response to concerns about the methods used for the previous estimates – a follow-up estimate published in 2015 using a simplified methodology.[603]

In 2008, the mass balance estimates were 136,491 tonnes of plastic packaging produced, 154,381 tonnes consumed, and 36,918 tonnes recovered. It is worth noting that there are significant limitations in this estimate because, due to the lack of consistent and verified data, many assumptions were made that may have introduced error. The estimates did not capture packaging material imported and exported around finished goods (as discussed in Section 5.2.2) and relied on the goodwill of third party agencies providing accurate data. Methodological limitations of this approach are described in detail by Packaging New Zealand in their 2015 report.

The more simplified approach was used to estimate recovery rates for 2013 based on export waste and population/GDP data. Assuming all plastic waste was exported, the estimate relied on Statistics NZ export data (as discussed in Section 5.2.2). The limitation of this is that the method excludes the amount of plastic reused or recycled onshore, or going to landfill. Using this method, the weight of plastic packaging estimated to be recovered in Aotearoa New Zealand was 41,900 tonnes per year, equating to 9.4 kg per person. This method does not provide an estimate for production or consumption.

ESTIMATES FROM 2008 SUGGEST THAT AROUND 150,000 TONNES OF PLASTIC PACKAGING ARE CONSUMED IN AOTEAROA NEW ZEALAND EVERY YEAR, WHICH EQUATES TO 30 KG PER PERSON

These estimates highlight how the shortcomings in data currently limit our ability to understand the scale of plastic in use and the need to establish a uniform approach to measure the types and volumes of plastic being used in Aotearoa New Zealand. It may be possible to address the lack of consistent, aggregated data on the amount of plastic in use by utilising, repurposing or extending existing data frameworks. An example is provided in Case Study 5.5.3, whereby information on the weight and material type of primary and secondary packaging is recorded through a supply chain database's product catalogue.

5.5.2 Knowledge gaps

As can be seen from comments throughout this report, we have serious gaps in our knowledge of how plastic moves through Aotearoa New Zealand. We are limited in our understanding of the amount and types of plastic that are:

- In imported finished products and packaging (see Section 5.2)
- Manufactured into products and packaging onshore (excluding those exported) (see Section 5.3)
- Reused (see Section 5.6)
- Collected as waste and sent to landfill or recycled (see Section 5.7).

[602] Packaging Council of New Zealand/Accord Secretariat, "New Zealand Packaging Accord 2004 Year Five Progress Report", 2009
[603] D Grimmond, "Review of Packaging Mass Balance Measurements", 2015

5.5.3 Case study: Capturing plastic packaging data through a supply chain database

Many manufacturers, brand owners, suppliers and retailers use the global GS1 database to share information with one another as a product moves through the supply chain from manufacture to purchase, within and between countries. A network of regional organisations, including GS1 New Zealand, connect their datasets through the global data synchronisation network (GDSN). A standardised language is used for product data across the network, via a data dictionary. GS1 New Zealand jointly maintains its database with GS1 Australia. Known as the National Product Catalogue, the database contains hundreds of thousands of products traded across and within the two countries. The global network requires certain core attributes (variables) to be captured. Any other requirements are localised, generally dictated by local regulation and/or data recipients.

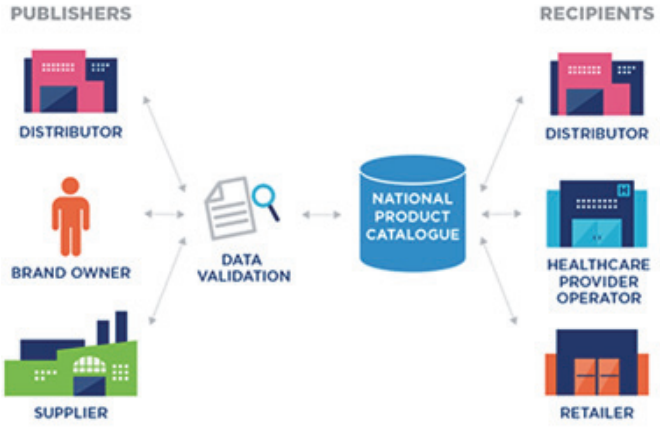


Figure 62 How data is shared between publishers and recipients in the GS1 National Product Catalogue. Image credit: GS1

In Aotearoa New Zealand, recording the packaging material type code was initiated in 2004 because of the Packaging Accord, as a voluntary means to provide the packaging data required by the Ministry for the Environment. This classifies packaging material by type of plastic, e.g. LDPE (#4), HDPE (#2) and bio-based plastics certified by the European standard.

Examples of additional packaging codes available within the GDSN but not yet captured in Aotearoa New Zealand include:

- Packaging level type: capturing primary, secondary and tertiary packaging so that packaging used throughout the supply chain is recorded (e.g. packaging for shipping or removed by retailer prior to sale)
- Packaging marked label accreditation: for example, whether the packaging is accredited as compostable according to specified standards
- Packaging recovery rate type: whether the packaging can be processed according to specified standards for e.g. composting or recycling
- Packaging recycled content type: the ratio of post-consumer recycled material (as defined by ISO 14021) to total material
- Packaging recycling process: whether packaging is compostable, energy recoverable, recyclable or reusable
- Packaging recycling scheme code: based on the resin identification codes
- Packaging reusability standard: whether the packaging meets certain standards for reuse.

An example of how packaging is coded within GS1's National Product Catalogue is below.

Comments	Attribute	Value
The main packaging is the bottle	packagingTypeCode	BOTTLE
It has a label	packagingFeatureCode	LABEL
It has a cap	packagingFeatureCode	CAP
	packagingWeight	1.2 GRM
The bottle is made of multiple polymers	packagingMaterialTypeCode	POLYMER_HDPE
	packagingMaterialCompositionQuantity	1 GRM
	packagingMaterialTypeCode	POLYMER_PE
	packagingMaterialCompositionQuantity	0.2 GRM
Next is the blister protection	packagingTypeCode	BLISTER_PACK
	packagingWeight	0.5 GRM
	packagingMaterialTypeCode	POLYMER_LDPE
	packagingMaterialCompositionQuantity	0.5 GRM
Next is the card backing	packagingTypeCode	CM
	packagingWeight	0.4 GRM
	packagingMaterialTypeCode	PAPER_PAPERBOARD
	packagingMaterialCompositionQuantity	0.4 GRM

In addition to consumer packaged goods, GS1 databases include apparel and footwear, consumer electronics and healthcare products. Notably, data recipients aren't limited to retailers. For example the New Zealand and Australian governments are data recipient for healthcare products and the Australian Tax Office for GST calculation purposes.

The key data recipients in Aotearoa New Zealand are Countdown and Foodstuffs, who between them have around 95% of market share for supermarkets. The products captured by these retailers cover 60-70% of all sales and include all major products. Voluntary uptake of the National Product Catalogue by suppliers is variable, with around 50% of Foodstuffs' product residing in the database at present. Countdown are in the process of onboarding their suppliers to the same database. These products are in the main from the larger FMCG suppliers and therefore their products account for a greater share of total sales in Aotearoa New Zealand. The use of GS1 standards (notably product identification/barcodes) across these two retailers is almost ubiquitous.

Further exploration of the potential to use GS1 and the National Product Catalogue to measure plastic use in Aotearoa New Zealand is warranted. There is a working group comprising GS1, Foodstuffs, Countdown, Retail NZ and NZ Food and Grocery Council underway to look at this.

5.5.4 Case study: Uncertainty around data on plastic beverage containers

Plastic beverage containers are one of the most common single-use plastic packaged products. These are manufactured onshore or imported as packaged goods. Two groups have estimated the production and recovery of beverage containers in Aotearoa New Zealand using different approaches. Other groups have used data from these studies to perform cost-benefit analysis of a container deposit scheme, but have not provided new estimates themselves.[604]

- Waste Not Consulting: Data from members of the Packaging Forum were shared with the group confidentially to be aggregated for analysis.[605]
  - Consumption data: Direct from some major brand owners but not independently verified; relied on market share estimates from brand owners to extrapolate consumption data.
  - Recovery data: Tonnages by material type direct from four recyclers and Fonterra but not independently verified. Used proportion of recovered material that were beverage containers from one recycler as well as information on geographical locations and populations to extrapolate data. Lack of data from one of Auckland's recyclers is a limitation that particularly affects PET (#1) and HDPE (#2) estimates.
- Envision: Data were derived from international data.[606] Note: Limitations in the methods used by this study have been discussed in detail.[607]
  - Consumption data: Per capita consumption rates were based on consumption data from South Australia who have an established CDS and converted to tonnage data. To validate estimates, data were also compared that from British Columbia in Canada and Western Australia.
  - Recovery data: Estimates based on questionnaire data from 16 Aotearoa New Zealand local authority representatives on the volumes of beverage containers recovered through kerbside and public space recycling programmes.

Table 26 Estimated rates of consumption and recovery of plastic beverage containers in Aotearoa New Zealand

		Consumption (tonnes)	Recovery (tonnes)	Recovery rate
Waste Not Consulting	PET (#1)	13,977	8,066	58%
	HDPE (#2)	13,512	5,455	40%
Envision	PET (#1)	14,274	Not reported	40%*
	HDPE (#2)	10,686	Not reported	40%*

*Estimated in this report to be below 40% and possibly as low as 30%

A material flow analysis of PET bottles through Aotearoa New Zealand estimated around 14,200 tonnes consumed annually, with 7,500 tonnes recovered (details in Appendix 11).

Information on the number of beverages produced/consumed and recovered/landfilled in Aotearoa New Zealand is not readily or easily available. The estimates of the tonnes of PET (#1) and HDPE (#2) consumed through beverage containers differ between the two methods and both are limited by the reliance on industry-reported data without audit by a third party. This makes understanding the potential impacts of efforts to improve plastic recovery, such as container deposit schemes, difficult. There is a need for comprehensive, verified data.

[604] Covec Ltd, "Evaluating the Costs and Benefits of Introducing a Container Deposit System for New Zealand: Summary of Analysis ", 2016 And Preston Davies, "Cost-Benefit Analysis of a Container Deposit Scheme: Report for the Auckland Council ", 2017
[605] Waste Not Consulting, "National Recovery Rate for Beverage Containers", 2018
[606] Envision, "The Incentive to Recycle: The Case for a Container Deposit System in New Zealand ", 2015
[607] W Snow, "Costs and Benefits of a Container Deposit Scheme for New Zealand: Review of the Packaging Forum's 2016 Cba of a Cds for New Zealand", 2016

5.6 How much and which types of plastic do we reuse onshore?

In order to reduce how much plastic we waste, it is favourable to reuse plastic products where appropriate. Reuse systems are important to combat the mountain of waste that comes from single-use plastic packaging for food and drinks, and can also be used in secondary and tertiary packaging along the supply chain such as for plastic pallets and crates. There are a few reuse systems that exist in Aotearoa New Zealand, but it is far from commonplace. It is even less common to measure the amount of plastic or other materials displaced by reuse systems. Globelet, a company who provide reusable cups at festivals, have estimated how many cups are displaced by their system (see Case Study 5.6.3). We need to track reuse systems in order to understand the amount of plastic waste diverted by their implementation.

5.6.1 Best practice

The WRAP UK provides a methodology and accompanying tool for quantifying the environmental and economic impacts of reuse.[608]

The key characteristics of the methodology include guidance on:

- What to include and exclude in the analysis (i.e. system boundaries)
- Product lifetimes and displacement effects of reuse
- Allocation of environmental or economic impacts to different parts of the supply chain
- Use of costs and prices
- Jobs and labour costs.

5.6.2 Knowledge gaps

At present, we do not have comprehensive information on all reuse systems displacing single-use plastics that are currently in place in Aotearoa New Zealand, and as a result we lack information on the types and weight of plastic currently being diverted from use/waste due to these existing reuse systems.

We also do not know the key products that future reuse efforts should focus on (prioritised by quantity, volume, material type etc.) or the potential environmental and economic impacts of reuse systems for Aotearoa New Zealand.

[608] Waste & Resources Action Programme (WRAP), "A Methodology for Quantifying the Environmental and Economic Impacts of Reuse", 2011

5.6.3 Case study: A reusable system to replace single-use cups

Globelet offers a reusable cup system for festivals and other events. The cups are made from recycled polypropylene (#5) and manufactured onshore.

Globelet provides the following statistics on their reuse system:[609]

- For a festival of 10,000 people, 15,000 reusable cups are required vs 50,000 single-use cups
- On average, 75% of cups get returned for reuse, 0.1% of cups are damaged (and then recycled into crates) and 0.8% are disposed of (but returned if waste management performed onsite). In comparison, all single-use cups are disposed of.
- So far, some cups have been used for 6 years for a particular event.
- Over 7 years, some cups have been used over 300 times – that's 1 cup preventing disposal of 300 single-use cups.
- In the last 8 years around Aotearoa New Zealand and Australia, Globelet has displaced 21 million disposable cups from going to landfill by providing a reusable cup system.

Figure 63 Cups from Globelet's reusable cup system

IN THE LAST 8 YEARS AROUND AOTEAROA NEW ZEALAND AND AUSTRALIA, GLOBELET HAS DISPLACED 21 MILLION DISPOSABLE CUPS FROM GOING TO LANDFILL BY PROVIDING A REUSABLE CUP SYSTEM

[609] Statistics on Globelet's reuse system are available at: https://www.globelet.com/blog

5.7 How much plastic do we recycle and waste?

To quantify the amount of plastic that New Zealanders waste, we need to consider the volume sent overseas and the amount that is dealt with onshore. Waste data reported here do not include the amount of plastic that leaks into the environment, or waste that is dumped, buried or burned in non-regulated sites.

Currently in Aotearoa New Zealand, plastic waste is managed through recycling (the majority of which is sent offshore) and sending waste to landfill. Plastic is collected for recycling or landfill through multiple systems, including household kerbside collection, public space bins and drop-off points, and commercial collection (as detailed in Section 3.6.4). The vast majority of waste plastic goes to landfill.

WASTE DATA DO NOT ACCOUNT FOR THE AMOUNT OF PLASTIC THAT LEAKS INTO THE ENVIRONMENT

5.7.1 No existing requirement for data collection

Currently, there are no statutory requirements under the WMA for councils to report waste data within a specific data framework or to report data externally. The WMA allows regulations to be developed under section 86 that could require a council to report on the expenditure of their waste levy money or, if set under section 49, on performance standards for the implementation of a WMMP. Under section 51 of the WMA, councils are required to prepare a Waste Management and Minimisation Plan (WMMP). Part of this is a waste assessment, for which data should be collected on waste quantities, projection of quantities, composition, source of waste, and destination of waste and diverted materials.[610] The Ministry for the Environment encourages councils to find as much relevant data as possible for their assessment and aim to have their data capture methodology consistent with those of other councils but, ultimately, the level of data collection is determined by a council's own circumstances, desired community outcomes, interest, and available resources.

Councils may also be limited in the data they can access if they contract out collection and recovery services to private operators due to how contracts are set up. Where private operators manage facilities and collection services under contract, some data may be obtained through key performance indicators in the contract they have with council or through bylaws. As the WMA only covers waste (and not recovered materials), bylaws can only be used to obtain data on plastic to landfill and not plastic for recycling.

5.7.2 Plastic collected for recycling

To understand the amount and types of plastic collected for recycling, data is required from the collection system or from the MRFs for all collection streams. The NRRP Taskforce estimated the annual tonnage of recycled plastic in Aoteaora New Zealand to be 45,000 tonnes, of which 90% was exported.[611]

Household kerbside

Details on the amount of plastic collected at kerbside for recovery may be found in the waste assessment published by each council, though not all councils report this data. Variations in what is reported reflect the different arrangements councils have with contracted recycling processors and variability in resourcing across councils.

[610] Ministry for the Environment, "Waste Assessments and Waste Management and Minimisation Planning – a Guide for Territorial Authorities", 2015

[611] Data for this estimate was compiled from a range of sources including information supplied in confidence during interviews for the National Resource Recovery Taskforce, available at: https://www.mfe.govt.nz/sites/default/files/media/Waste/national-resource-recovery-project-redacted.pdf

When councils include data on recovered plastics in their waste assessment, most report the total tonnage, and the percentage of plastic that makes up the total kerbside collection. Some councils report the type of plastics recovered grouped as PET (#1), HDPE (#2) and mixed plastics. Fewer councils report material type by colour (see Case study 5.7.3). Overall, few councils disclose the amount of plastic collected at kerbside for recycling.

The National Resource Recovery Project Situational Analysis estimated the annual tonnage of plastic collected for recycling from household sources to be 25,000 tonnes (roughly 55% of the total recovered plastic – the rest being from commerical and other sources, as discussed below).[612] The analysis reported the typical composition of plastic waste within total kerbside recycling collection as 2% PET (#1), 2% HDPE (#2) and 4% mixed plastics, excluding contamination, but noted that there is significant variation in the materials accepted to make up these grades. For example, while all councils accept PET (#1) in kerbside recycling, only 71% accept PS (#6).

Available data for each council can be found in their respective waste assessments. For example, in 2016 the plastic component of Auckland's kerbside recycling was reported to be 7,172 tonnes, representing 5% of total quantity of recyclables collected. Plastics are separated into three categories in Auckland: 1,039 tonnes HDPE (#2), 2056 tonnes PET (#1) and 4,077 tonnes mixed plastic in 2016.[613]

ANNUALLY, 25,000 TONNES OF RECYCLED PLASTIC ARE COLLECTED FROM HOUSEHOLDS, WHICH IS THE EQUIVALENT OF THE WEIGHT OF PLASTIC BEVERAGE CONTAINERS CONSUMED IN AOTEAROA NEW ZEALAND

[612] Data for this estimate was compiled from a range of sources including information supplied in confidence during interviews for the National Resource Recovery Taskforce, available at: https://www.mfe.govt.nz/sites/default/files/media/Waste/national-resource-recovery-project-redacted.pdf

[613] Adapted from data in Auckland Council, "Auckland's Waste Assessment 2017", 2017

Public place collection

Data on rates of recycling have been published in the Public Place Recycling voluntary product stewardship scheme 2016 annual report.[614] In the four years included in the report, a total of 462 tonnes of plastic rubbish had been collected for recycling via public place collection systems.

Table 27 Annual tonnes of plastic recycled through the public place collection scheme

	Commercial (tonnes)	Councils (tonnes)
2012	87	52
2013	99	17
2014	102	18
2015	73	14

BETWEEN 2012 AND 2015, AROUND 460 TONNES OF PLASTIC WAS RECYCLED THROUGH THE PUBLIC PLACE COLLECTION SCHEME IN AOTEAROA NEW ZEALAND

Soft plastic recycling scheme

Most local council recycling schemes do not collect soft plastic, but the industry-led Soft Plastic Recycling Scheme collected 365 tonnes (approximately 91 million bags) in 2017, roughly 50 tonnes per month.[615] The nationwide Soft Plastics Recycling Scheme was put on hold in December 2018 after recyclers in Australia stopped accepting the material, but as of October 2019 has resumed in Auckland, Hamilton and Wellington at approximately 50 locations, with onshore processors using the plastic for products such as fence posts and ducting.[616]

IN 2017, 365 TONNES OF SOFT PLASTICS WERE RECYCLED – BUT A LACK OF RECYCLING MARKET FOR THESE PLASTICS MEANT THAT IN THE FOLLOWING YEAR, PLASTIC WAS STOCKPILED WHILST NEW ONSHORE MARKETS WERE DEVELOPED AND A PERCENTAGE OF NON-CONFORMING PLASTIC WAS LANDFILLED

Commercial recycling collections

Unlike household waste, commercial plastic waste tends to be clean and homogeneous, and as a result has been less impacted by restrictions imposed by China relating to importing contaminated waste plastic. The National Resource Recovery Taskforce did not report the proportion of recycling waste that is from commercial sources, but given that 55% is reportedly from household waste, we can assume that commercial sources contribute less than 45% of recycled plastic in Aotearoa New Zealand (20,000 tonnes or less).

[614] The Packaging Forum, "Public Place Recycling: Voluntary Product Stewardship Scheme "
[615] Circular Economy Accelerator Sustainable Business Network, "New Zealand's Plastic Packaging System, an Initial Circular Economy Diagnosis", 2018
[616] Details about changes to collection for the Soft Plastics Recycling Scheme available at: https://www.recycling.kiwi.nz/solutions/soft-plastics

5.7.3 Case study: Palmerston North City Council recycling

Palmerston North City Council collects over 4,000 tonnes of recycling from the Palmerston North kerbside collection service and owns their own MRF, which receives recycling from Horowhenua City Council, Waste Management – Palmerston North and New Plymouth, and Envirowaste – Palmerston North.

Annually, the MRF processes around 4,800 tonnes of material. The composition of the products are: 70% fibre; 13% plastics; 4% steel; 2% aluminium and 11% waste. These figures vary depending on the season and region of collection, but are reflective of the average values.

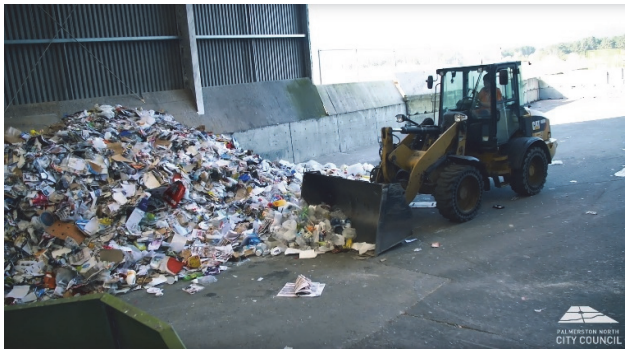


Figure 64 The MRF operated by Palmerston North City Council. Photo credit: PNCC

Currently, Palmerston North City Council sells 3 different grades of plastics to companies based in Aotearoa New Zealand. Clear PET (#1) is sold to Flight Plastics (see Case Study 3.6.8) and HDPE (#2) and PP (#5) are sold to a company based in Palmerston North, Aotearoa NZ Made.

The tonnages of plastic collected by Palmerston North City Council are shown in Table 28. There has been a decline over time in the total volume of plastic collected, including for higher value plastics (clear PET (#1) and HDPE natural (#2)).

Table 28 Palmerston North City Council kerbside collection by plastic grade

	Tonnes (% of total collection)			
	2015/16	**2016/17**	**2017/18**	**2018/19**
PET clear (#1)	209.56 (3.72)	186.42 (3.90)	189.02 (3.95)	199.68 (4.65)
HDPE natural (#2)	93.72 (1.66)	81.4 (1.70)	70.62 (1.47)	74.36 (1.73)
HDPE coloured (#2)	35.76 (0.63)	78.24 (1.63)	99.6 (2.07)	81.36 (1.90)
PP (#5)*	NA	NA	NA	7.2 (0.16)
Mixed plastics (#s 3,4,6,7)	NA	NA	NA	240.48 (5.60)
Mixed plastics (#s 3-7)	206.88 (3.67)	157.68 (3.30)	213.84 (4.45)	NA
Waste	735.41 (13.06)	784.19 (16.33)	784.19 (16.33)	570.32 (13.28)
Total collected for recycling	5628	4802	4805	4293

*May 2016 onwards, HDPE coloured (#2) separated from mixed plastics; January 2019 onwards, PP (#5) separated from mixed plastics (#s 3,4,6,7).

OF THE 603 TONNES OF PLASTIC COLLECTED FOR RECYCLING BY PALMERSTON NORTH CITY COUNCIL'S KERBSIDE COLLECTION IN 2018/19, 362 TONNES WERE RECYCLED ONSHORE

5.7.4 Plastic sent overseas for recycling

Traditionally, our country has sent a significant proportion of our plastic waste (~90%) overseas. The amount of exported plastic waste is captured within the 'Plastics and articles thereof' trade commodity.[617] In 2017, China instituted a new policy that significantly reduced their intake of low-value waste. Between 2016 and 2018, the tonnage of plastic waste exported from Aotearoa New Zealand has decreased overall (see Figure 65). The most significant changes have been a decrease in waste exported to China and Hong Kong, as a result of policy changes, and a subsequent increase in export to Indonesia and Malaysia. As described in Section 1.2, China's National Sword policy, recent policy changes by South East Asian Nations, and ammendments to the Basel Convention have changed the environment in which MRFs can export plastic waste. These changes highlight the need for onshore processing capabilities for recycling plastic in Aotearoa New Zealand and incentives to reduce the use of non-recyclable plastics so that recyclable plastic is not landfilled here.

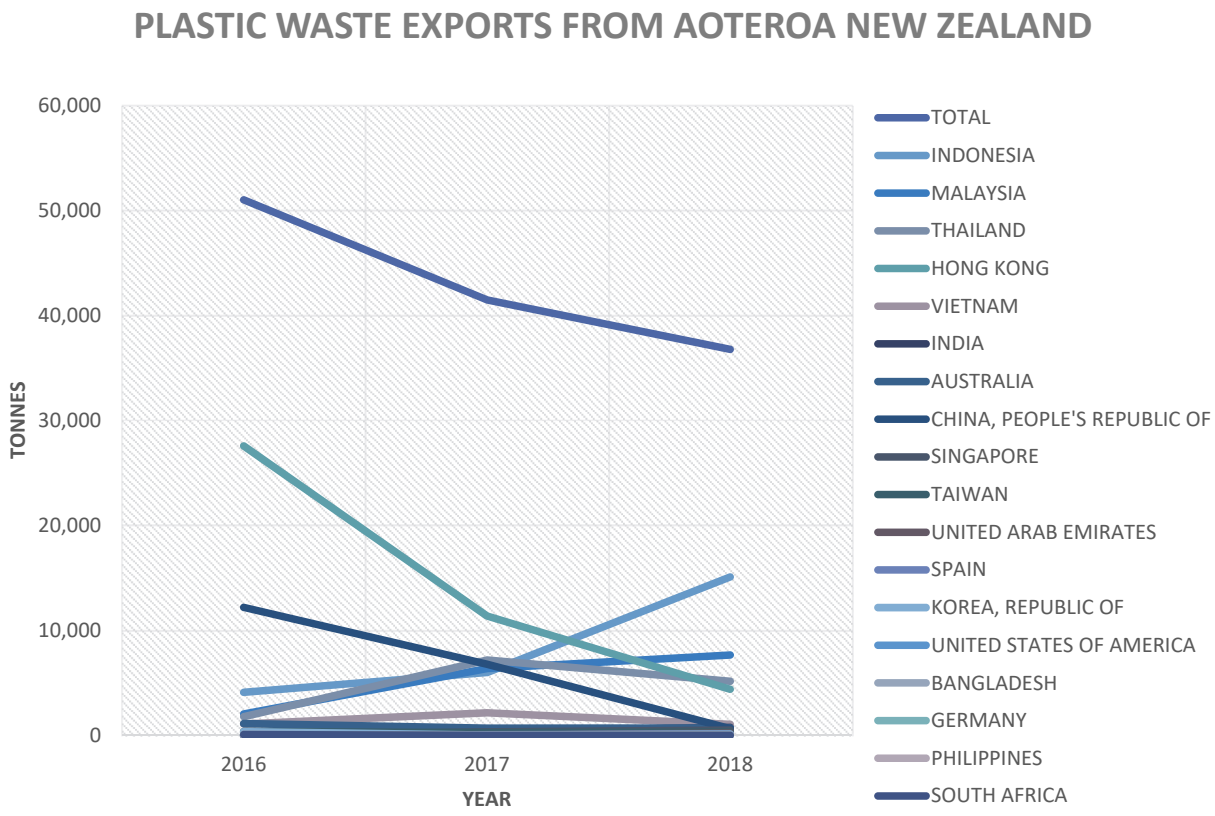


Figure 65: Tonnes of plastic waste exported from Aotearoa New Zealand.

PLASTIC WASTE EXPORT DATA SUGGESTS THAT AROUND 15,000 TONNES OF PLASTIC WASTE THAT WAS PREVIOUSLY SENT OFFSHORE IS EITHER BEING RECYCLED, STOCKPILED OR LANDFILLED IN AOTEAROA NEW ZEALAND EACH YEAR

[617] Codes: 3915100000; 3915200000; 3915300000; 3915900000.

5.7.5 Plastic recycled onshore

A proportion of the plastic material collected for recycling in Aotearoa New Zealand is recycled onshore. This has increased in recent years in response to China's National Sword policy, with the opening of new recycling facilities such as Flight Plastics. Based on the amount of plastic collected for recycling and exported, around 10,000 tonnes of plastic is recycled onshore. That is likely to be an overestimate as a proportion of plastic collected for recycling will be contaminated and unable to be recycled.

5.7.6 Plastic sent to landfill

In Aotearoa New Zealand, plastic that is not recycled goes to landfill. Landfills are classified into 5 classes as municipal (class 1) and non-municipal (classes 2-5). Each accepts different types of waste, described in detail by WasteMINZ.[618]

Waste levy

Under the WMA, a disposal levy of $10/tonne was introduced for class 1 landfills. Class 1 landfills accept all waste, but represent only 11% of consented waste disposal facilities. Class 2-5 landfills are not levied under the Act. This means that industrial, commercial, household and municipal solid waste types are always levied, but other waste types are only levied if they are landfilled in a class 1 landfill. Disposal sites can be 'consented' or 'permitted'. A permitted activity site does not require resource consent or monitoring and as such the ability to collect data for these sites is limited.

The 11% of landfills that are currently levied are required to submit monthly information on the net amount of waste disposed of at their facilities (gross tonnage minus diverted tonnage) in order to pay the levy, so there is good quality data available on the quantity of material that is going to levied disposal sites. Data is managed through the Ministry for the Environment's online waste levy system (OWLS). Expansion of OWLS to include other landfills and to collect further information could be a potential way to improve data on tonnes of waste sent to and diverted from landfill.

In August 2018, the Ministry for the Environment announced that part of their waste work programme would include looking at options to expand the waste dispoal levy to apply to currently non-levied landfills.[619]

EXPANSION OF OWLS TO INCLUDE OTHER LANDFILLS AND TO COLLECT FURTHER INFORMATION COULD BE A POTENTIAL WAY TO IMPROVE DATA ON TONNES OF WASTE SENT TO AND DIVERTED FROM LANDFILL

[618] WasteMINZ, "Technical Guidelines for Disposal to Land", 2018

[619] Ministry for the Environment, Waste work programme to tackle tough problems (19 August 2018); Available at: http://www.mfe.govt.nz/news-events/waste-work-programme-tackle-tough-problems

Tonnes of waste to landfill

A study reviewing potential impacts of adjustments to the waste levy estimated the total waste generation for Aotearoa New Zealand in 2015 to be 15,311,725 tonnes, of which 9,660,315 tonnes were landfilled and roughly a third of that into class 1 (municipal) landfill (see Table 29).[620]

Table 29 Tonnages and proportion of plastic waste to landfill and recovery in Aotearoa New Zealand in 2015

Waste destination	Tonnes	Data source for tonnage
Class 1 Landfill	3,220,888	2015 data from Ministry for the Environment (2016) Monthly Levy Graph (background data)
Class 2 Landfill	2,575,771	Estimated from 2013 data with waste growth equivalent to change in real GDP applied from Ministry for the Environment (2014) New Zealand Non-Municipal Landfill Database, October 2014
Class 3 Landfill	64,394	
Class 4 Landfill	3,799,262	
Farm dumps	1,362,666	
Recovery	4,288,743	
Total waste generated	15,311,725	Estimate based on data from various sources (details provided in report)

Though technically all types of landfill accept plastic waste, the proportion of plastic waste going to each class of landfill differs. Studies of landfill composition suggest that plastic makes up a significant proportion of waste in municipal landfill (see Section 5.7.7), but a very small (or nil) proportion of non-municipal landfill (see Appendix 12 for more information). Therefore, to estimate the total volume of plastic waste going to landfill, we focus here on municipal landfill.

[620] Eunomia Research & Consulting Ltd, "The New Zealand Waste Disposal Levy: Potential Impacts of Adjustments to the Current Levy Rate and Structure", 2017

Municipal landfill

Data on tonnages of waste to sent to municipal landfill (class 1) in Aotearoa New Zealand have been aggregated by the Ministry for the Environment (or contractors) in order to review the effectiveness of the waste disposal levy.The most recent publically available estimates on the tonnages of waste were published in 2017. For the period July 2013 to June 2016, levied waste disposal facilities received a total of 10,681,295 tonnes of gross tonnage of waste. From this, 1,207,786 tonnes of material were diverted, leaving total net waste tonnage of 9,473,509 tonnes.[621] Using this data, the OECD reported Aotearoa New Zealand's total and per capita waste[622] (see Figure 66). Except for 2012, net waste to levied landfills has increased every year since the levy was introduced. Note that plastics is not the only type of waste reported in these figures and that this is the same data from which the estimate in Table 29 is drawn.

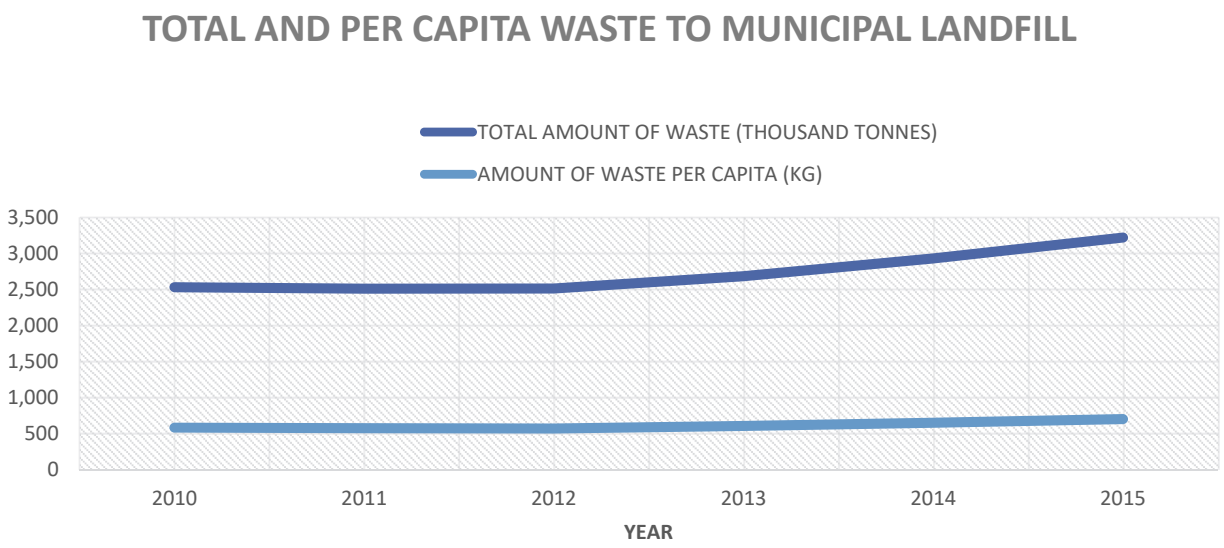


Figure 66 Total and per capita waste to municipal landfill in Aotearoa New Zealand

IN 2015, OVER 3 MILLION TONNES OF WASTE, INCLUDING PLASTIC, WENT TO MUNICIPAL LANDFILL IN AOTEAROA NEW ZEALAND

The waste levy was implemented in 2009, therefore we would ideally compare tonnages of municipal waste to landfill before and after this time to determine the effectiveness of the waste levy. However, we cannot compare these due to changes in data collection methods.[623] It is also important to consider that the global financial crisis of 2008 led to decreases in consumption and waste and changes around that time may not be solely attributable to the levy.

[621] Ministry for the Environment, "Review of the Effectiveness of the Waste Disposal Levy 2017", 2017
[622] OECD, "Municipal Waste Database", 2015
[623] The way municipal landfill data was collected changed in 2010 due to the Waste Minimisation Act 2008. Data collected prior to 2010 is considered imprecise, and the Ministry for the Environment has advised not to compare this with data collected from 2010 onwards. Details at: http://www.mfe.govt.nz/more/environmental-reporting/reporting-act/waste/solid-waste-disposal-indicator/quantity-solid-waste

5.7.7 Proportion of landfilled waste that is plastic

To understand the amount of plastic waste we are landfilling, we need to know the proportion of the waste going in to landfill that is plastic. The Ministry for the Environment website states that, "at present we don't have data on the composition of what's going into landfills or the amount of resources that are being diverted from landfill".[624] Where the Ministry for the Environment has sampled waste composition at landfill, they have followed the Solid Waste Analysis Protocol (SWAP).[625] Waste is surveyed at domestic source or disposal facilities, using a specific sampling regime and classification system, to estimate proportions.

Through SWAP analysis at a sample of municipal waste disposal facilities between 2004 and 2012, it was shown that the proportion of plastic decreased between 2004 and 2008, but increased between 2008 and 2012 (see Figure 67).[626] In 2012, plastic made up a large proportion of waste, second only to food and garden waste. Together, plastic and food and garden waste made up nearly 40% of municipal waste. Also notable is the increase in textile waste, a proportion of which will be synthetic materials of plastic fibre. These surveys have not been conducted by the Ministry for the Environment since 2012.

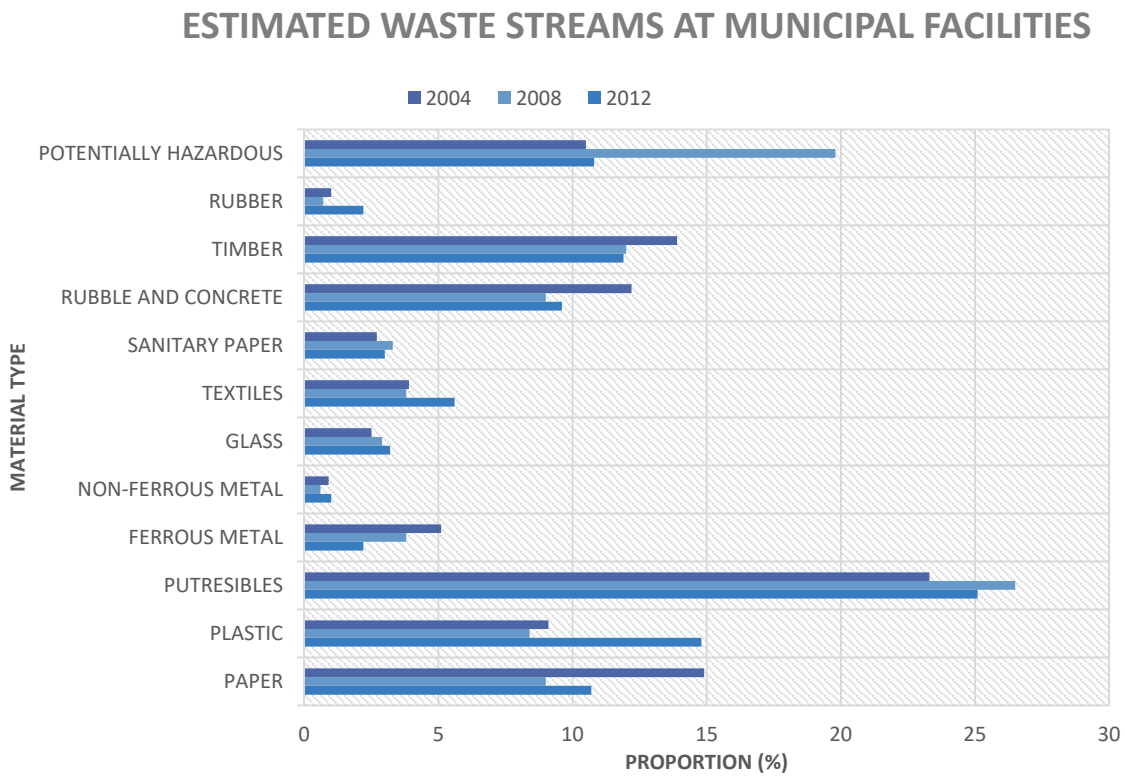


Figure 67 Estimated proportion for common waste streams at municipal waste disposal facilities from 2004 to 2012. Source: Ministry for the Environment

[624] Ministry for the Environment, Waste and Government; Available at: http://www.mfe.govt.nz/waste/what-government-doing
[625] Tonkin & Taylor, "New Zealand Non-Municipal Landfill Database", 2014
[626] Ministry for the Environment, "Review of the Effectiveness of the Waste Disposal Levy 2017", 2017

More recently, Perrot et al. estimated landfill waste composition based off publically available regional council data between 2011 and 2017.[627] Their estimates put plastics at 12.1% of municipal landfill waste (see Figure 68). This aligns with Auckland Council's estimates of the proportion of waste to landfill that is plastic.[628] Redvale Landfill and Energy Park estimated that plastics were around 14% of the waste stream (see Case Study 3.8.1).

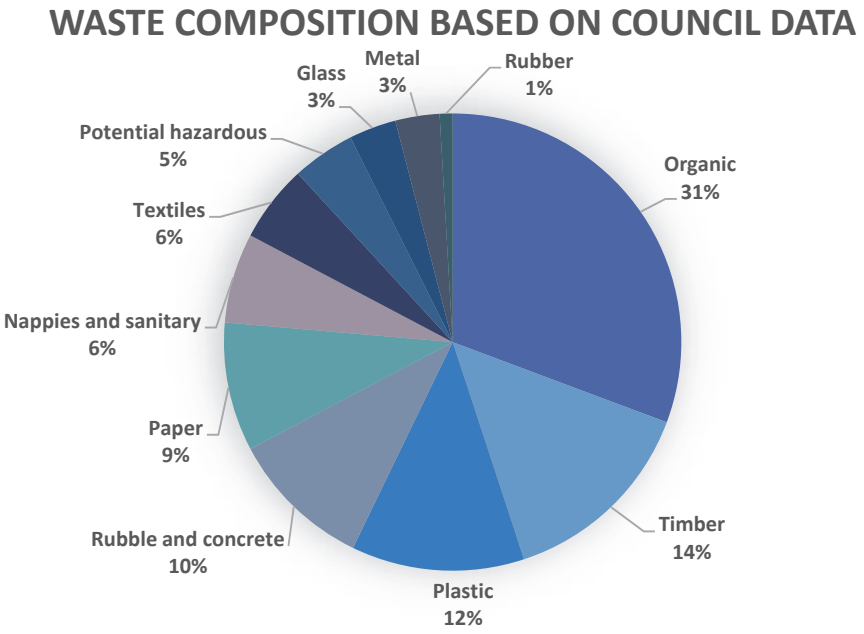


Figure 68 Waste composition according to regional council data from Perrot et al.

Private contractors often assess waste composition to landfill for clients, including councils. Therefore additional and more recent data do exist, but it is not aggregated, easily accessible or in the public domain. The main reason for the lack of aggregated, accessible data is that there is no requirement for commercial contractors to provide data to local or central government under current law. Some councils are introducing bylaws to require waste operators to be licensed and ensure these licensed waste operators report waste data.[629]

THE MAIN REASON FOR THE LACK OF AGGREGATED, ACCESSIBLE DATA IS THAT THERE IS NO REQUIREMENT FOR COMMERCIAL CONTRACTORS TO PROVIDE DATA TO LOCAL OR CENTRAL GOVERNMENT UNDER CURRENT LAW

Based on available data, we can make a conservative estimate of the proportion of plastic waste to landfill by multiplying the total waste to class 1 landfills (approximately 3.2 million tonnes) by the estimated proportion of waste that is plastic (12%), giving a total of 384,000 tonnes.

IF 12% OF WASTE IS PLASTIC IN CLASS 1 LANDFILL, AROUND 380,000 TONNES OF PLASTIC WOULD HAVE BEEN LANDFILLED IN 2015

[627] Perrot, J.-F. Municipal Waste Management Strategy Review and Waste-to-Energy Generation Potential in New Zealand. Master's Thesis, The University of Auckland, Auckland, New Zealand, 2018
[628] Auckland Council Waste Assessment 2017
[629] Ministry for the Environment, "Waste Assessments and Waste Management and Minimisation Planning – a Guide for Territorial Authorities", 2015

Diversion potential of plastics to landfill

During a SWAP analysis, the proportion of plastic waste sent to landfill that was recyclable may be recorded. Some councils have published this information within their waste assessments. For example, Auckland Council reported that 0.5% of the total proportion of plastic waste (excluding kerbside waste) sent to the Auckland Council owned Waitakere transfer station in 2016 was recyclable – which equates to 6 tonnes per week.[630] For kerbside refuse, the diversion potential was reported at 0.5% of total waste for PET (#1) and HDPE (#2) containers (0.05 kg per bin) and 1.2% of total waste for plastics #3-7 containers (0.12 kg per bin).

5.7.8 Waste from manufacturing process

A proportion of plastic that goes into the manufacturing process is lost as scrap material or rejected products due to design issues or defects. The most recent published data on the amount of pre-consumer industrial waste in Aotearoa New Zealand comes from a 2005 report by Plastics NZ.[631] The report identified 4,487 tonnes of waste from this source for recycling in New Zealand. The report figure excludes plastic waste that was recycled in-house through feedstock recycling. Recyclability is not an issue for this plastic as it has generally come from a clean manufacturing stream, as long as the plastic type is recyclable. Plastics NZ have set up a database to allow manufacturers to exchange manufacturing waste to improve its utilisation.

5.7.9 Knowledge gaps

While there are several studies reporting varying levels of data for landfilled or recovered waste, comprehensive data is not available or consistent in order to aggregate a national data set for plastic waste that captures weight by material type.

[630] Auckland Council, "Auckland's Waste Assessment 2017", 2017

[631] Withington, N. (2005) Sustainable End-of-life Options for Plastics in New Zealand-Plastics New Zealand Research Report. Plastics NZ, PO Box 76 378 Manukau, Auckland.

5.7.10 Case study: Agricultural plastic waste

Assessments of plastic waste in the agricultural industry have been performed by GHD for the Environment Canterbury Regional Council in 2013 and the Waikato and Bay of Plenty Regional Councils in 2014.[632] Council waste assessments also include some farm waste data but are not included in this case study. These three regions have the highest number of farms in Aotearoa New Zealand. The same survey methodology was used across both studies, but the breakdown of waste type differed, limiting comparison of specific materials across both. There were 53 farms surveyed for Canterbury and 69 for the Waikato and Bay of Plenty. Non-natural rural waste includes waste streams from dairy, livestock, arable farming and horticulture. Key findings:

- National projections based on these assessments estimate over 2.1 million tonnes of rural wastes (including plastics) are produced annually in Aotearoa New Zealand (37 tonne average per property multiplied by 58,071 rural properties in New Zealand, not accounting for variations in activity by different farm type)
- Plastic was one of the most prevalent non-natural rural wastes. Types of plastic waste are varied and some are hazardous. Examples include containers, drums, silage and baleage wrap, netting, mulch film and crop cover, agrichemical containers, animal health plastic packaging and plastic sheep dip, fertiliser bags, domestic refuse (see Appendix 12)
- Almost all sites burn, bury and/or bulk store waste indefinitely as a disposal strategy (92% Canterbury; 100% Waikato and Bay of Plenty), which has the potential to impact water quality in streams, rivers and groundwater, and air quality
- Significant differences in plastic use may result from different farming infrastructure – for example, areas where farms had irrigated paddocks there was a reduced volume of plastics from wraps and sacks.

Table 30 Example waste streams of plastic from rural properties

Waste type	Canterbury			Waikato/Bay of Plenty		
	Total surveyed (tonnes)	Average/farm (tonnes)	Total for 8,826 farms x average	Total surveyed (tonnes)	Average/farm (tonnes)	Total for 14,685 farms x average (tonnes)
Containers	1.7	0.03	264.78	2.2	0.03	440.6
Drums	2.7	0.05	441.3	5.0	0.07	1027.9
Silage wrap	14.8	0.3	2647.8	11.4	0.2	2937.0
Netting	10.9	0.2	1765.2	9.1	0.1	1468.5
Mulch film and crop cover	2.6	0.05	441.3	5.8	0.1	1468.5

These studies estimate that these three regions generate over 700 tonnes of plastic containers per year, which is over half the weight of the 1200 tonnes of 0-60 litre containers estimated by Agrecovery for 2018.

While these findings need to be verified by further studies, they do indicate that there is a significant amount of plastic waste from agricultural settings and highlight the need to ensure the agricultural sector is considered when rethinking plastics in Aotearoa New Zealand.

[632] GHD, Non-natural rural waste: Site survey data analysis (2013), prepared for Environment Canterbury Regional Council; Available at: https://api.ecan.govt.nz/TrimPublicAPI/documents/download/1851763 and GHD, Rural waste surveys data analysis: Waikato and Bay of Plenty (2014), prepared for Waikato Regional Council ; Available at: http://www.waikatoregion.govt.nz/assets/PageFiles/30542/TR201455.pdf

5.7.11 Case study: Plastic waste during new-build construction

During 2017-2018, Cerqueira evaluated the use of source separation for the recovery of construction waste on an active new-build construction site.[633] The site chosen was a residential development of approximately 350 m^2 floor area in Auckland. Among other construction materials, approximately 80 kg of mixed plastics were able to be separated into soft and hard grades and sent to Visy recycling or Mitre 10 to achieve 100% diversion. In this case study, of the 6.8 tonnes of waste audited, a total of 4.1 tonnes were diverted from landfill representing 60% waste recovery and diversion. However, contractors have indicated to Green Gorilla that separation at source is not sustainable due to the time required (and costs incurred as a consequence).

Figure 69 An example of the types of plastic pipes used in construction

An exploratory study is underway at Unitec to identify and quantify plastic waste streams, and their potential for recycling, from new-build construction. The study will inform a broader national study of the potential for diversion, of all materials, within the new-build and deconstruction sectors, including the economic implications of a range of models for construction waste processing with a medium-term goal to provide economic and sustainable alternatives to landfilling.

This study measures the waste product of the new build process, but does not measure the waste from construction demolition.

APPROXIMATELY 80 KG OF MIXED PLASTIC WASTE WAS GENERATED FROM A RESIDENTIAL DEVELOPMENT OF 350M^2 FLOOR AREA IN AUCKLAND

[633] Cerqueira, I.B.S. (2018). Waste Recovery and Landfill Diversion by Source Separation on an Active Construction Site. A final year project report MG7101, submitted in partial fulfilment of the requirements for the Degree of Bachelor of Engineering Technology (BEngTech, Civil), Unitec Institute of Technology (unpublished).

5.8 Opportunities for capturing waste data

5.8.1 National Waste Data Framework

In response to the lack of standardisation in waste data collection in Aotearoa New Zealand, WasteMINZ developed a National Waste Data Framework (NWDF) that could be implemented by both local government and the waste industry across the country. This was articulated by the National Waste Data Framework Project:[634]

> "Lack of standardisation has meant it is, at the least, time-consuming and difficult to meaningfully collate and share data, at any level, or to accurately monitor the impacts of interventions on waste flows. This has long been recognised as preventing both the public and private sectors from effectively planning, monitoring, and reporting on waste issues and developing and prioritising solutions."

Stage 1 of the project was completed in 2015 and was supported by a grant from the Waste Minimisation Fund and contributions from local government partners.

The framework:

- Establishes a set of definitions to act as a common language for collecting and reporting waste data
- Determines what data are gathered
- Determines who gathers these data
- Specifies how the target data are gathered
- Directs who data are reported to
- Sets out how the data that are collected are collated and presented.

The framework sets out protocols for gathering and reporting data on solid waste that is disposed of at disposal facilities (as defined by the WMA 2008), and also for presenting information about waste and diverted material services and facilities. The seven reporting indicators established by the NWDF collect data required for the WMMP assessment which each council has to perform.

The framework is designed with councils at the centre of data collection. Within the NWDF documentation, this is cited to be a result of the Ministry for the Environment under the previous government stating a clear preference for voluntary methods, in the first instance. In the four years since completion, efforts to align data collection with the NWDF have been varied due to the voluntary nature of the framework.

- **Currently implementing the framework:** Two regional groups of councils are currently working to implement the framework. Wellington councils (8 councils in total), and the Bay of Plenty and Waikato Councils (16 councils in total), as well as Auckland Council.
- **Active efforts to implement:** Several councils have made active efforts to implement the framework at some level, such as aligning weighbridge codes, using the NWDF data in their Waste Assessments, or initiating licensing of waste operators/adopting new bylaws. This includes Central Hawkes Bay, Dunedin, Hamilton, Hutt City, Mackenzie District, Matamata-Piako, Opotiki, Palmerston North, Ruapehu, South Waikato, Tauranga, Timaru, Waipa, Whakatane, Wellington and Western Bay.
- **Some alignment:** around 40 councils have made some level of alignment of their data collection with the NWDF. This is mainly through SWAP audit methodology aligning the 'activity source data' with the NWDF.
- **No alignment:** the remaining councils may have made no steps to begin aligning their data collection with the NWDF.

[634] Details of the National Waste Data Framework, including all published reports, are available at: https://www.wasteminz.org.nz/projects/national-waste-data-framework-project/

The Ministry for the Environment highlights the NWDF as a resource for councils to refer to but does not mandate use, though this is possible via the WMA. Given that the NWDF is ready to go and could be implemented by all councils due to not being overly prescriptive or rigid, mandating use would advance waste data quality in Aotearoa New Zealand. The limitations of the framework, such as the lack of centralised data collection/maintenance and the fact it doesn't address diverted materials or non-levied landfill sites could be addressed over time through a clear and structured plan.

IN THE 4 YEARS OF VOLUNTARY IMPLEMENTATION OF THE NATIONAL WASTE DATA FRAMEWORK, ONLY AROUND ONE THIRD OF LOCAL COUNCILS ARE CURRENTLY WORKING TO FULLY IMPLEMENT THE FRAMEWORK

5.9 How much plastic is leaking into the environment in Aotearoa New Zealand?

A recent study that quantified the global environmental losses of plastics across the entire plastic value chain found that approximately 6.2 million tonnes of macroplastics and 3 million tonnes of microplastics were lost into the environment in 2015. Mismanaged municipal solid waste in lower income countries was identified as the major source of larger plastic, while abrasion of tyres and road markings were the major sources of microplastics.[635]

In the context of Aotearoa New Zealand, there are relatively recent approaches to measuring litter in certain parts of the environment. These studies can help us begin to understand the scale of the plastic pollution problem locally, identify the most problematic plastic products, and provide a baseline to track improvements based on behaviour or policy changes. It is important that ongoing efforts among researchers and citizen scientists to measure the scale and impact of plastic pollution do not occur in silos, rather that frameworks for collection are consistent and learnings are shared between groups.

Māori use both quantitative and qualitative approaches to assess and monitor the environment and ecosystems (e.g. waterways and taonga species). This has led to ways of knowing how to read critical shifts in the environment that can tell us when to restrict use of resources or change practices that are damaging. Ongoing observations of the natural environment are often actively led by local iwi/hapū.

5.9.1 Land-based plastic pollution

Most plastic that ends up in the marine environment comes from land. This occurs through littering behaviour, mismanaged collected plastic waste, and also the loss of plastic that was intentionally placed in the environment – for example, through landfill disasters (see Case Study 4.20.2).

National Litter Survey

On behalf of the Public Place Recycling Product Stewardship Scheme, which aims to increase recycling and abate loose litter, Waste Not Consulting conducted two National Litter Surveys in Aotearoa New Zealand. The first, published in 2015,[636] provided baseline data prior to the initiation of the recycling scheme. The purpose of the second report, published in 2018,[637] was to monitor outcomes of the scheme.

Between 2015 and 2018, there was a 5% reduction in the number of litter items counted. However, there was a 22% decrease in the number of transects that had no or low amounts of litter.

Table 31 National Litter Survey: baseline and outcome monitoring for the Public Place Recycling Product Stewardship Scheme

	2014/15	2017/18
Visible and bulky litter	18,620 items/581,764m2 of public space 32 items/1,000m2 surveyed	17,735/581,764m2 of public space 30.5 items/1,000m2 surveyed
Transects graded as having virtually no visible litter or mostly free of visible litter	87%	65%

For plastic litter specifically, items were classified by type of plastic for drink packaging (e.g. PET (#1) drink containers and HDPE (#2) drink containers) but for food packaging plastics were grouped with multi-material items.

The 2017/18 litter survey results identified a significant proportion of litter was plastic packaging. Food packaging of plastic or mixed materials made up 13.3% of the litter count, and plastics drinks packaging made up 5.8% (excluding

[635] Ryberg et al., "Global Environmental Losses of Plastics across Their Value Chains,"
[636] Waste Not Consulting, "National Litter Survey 2014-2015: Summary of Results", 2015
[637] Waste Not Consulting, "National Litter Survey 2017-2019: Summary of Results", 2018

'other drink packaging', which may contain some plastic items such as bottle tops). Of the plastic drinks, nearly half (2.3%) were PET (#1) bottles, which are recyclable. Soft plastic packaging contributed 9.1% of litter, but was not specifically measured in the baseline data.

These findings illustrate that people mismanaging single-use plastic packaging is a key contributor to plastic in the environment in Aotearoa New Zealand.

Keep New Zealand Beautiful Litter Audit

In 2019, Keep New Zealand Beautiful (KNZB) carried out a comprehensive National Litter Audit, which compiled data through the physical inspection and visual counting of litter in a number of specific, fixed sites.[638] The methodology was based on international best practice and developed in consultation with Statistics NZ, the Ministry for the Environment and the Department of Conservation. The information collected provides empirical data on regions, the quantities, types, locations, and brands of litter deposited across the country.

Key findings of the litter audit include:

- The overall average number of items was 118/1,000 m^2 across the 413 sites surveyed
- The overall average litter weight was 0.62 kg/1,000 m^2, and the overall average estimated volume was 7.35 L/ 1,000 m^2
- Plastic items contributed both the second largest litter weights and numbers of litter items to the overall national litter stream
- Cigarette Butts and vaping cartridges – which are both plastic – were the most frequently identified items per 1,000 m^2 nationally, however they contributed the smallest weights and volumes to the litter stream.

[638] Keep New Zealand Beautiful, "National Litter Audit", 2019

5.9.2 Plastic pollution in waterways

Land-based plastic pollution finds its way into the ocean through waterways. Understanding the pattern and extent of plastic travelling through waterways is crucial to inform efforts to capture leaked plastic and prevent it entering the marine environment.

Palmy Plastic Pollution Challenge

A citizen science programme in Palmerston North reported preliminary findings from a litter audit to benchmark all forms of plastic pollution in the city that took place in April 2019.[639] Plastic litter was measured across 41 sample sites from the city streams then analysed by volunteers though a process of sorting, counting and weighing items of stream litter/waste.

In total over 11,000 litter items were collected from the sample sites, representing approximately 3% of the total length of the main city streams. This finding equates to approximately 2,680 items of litter / plastic per site (1,000 m^2). Food wrappers made up almost 25% of all items collected. The initial estimate is that this equates to over 360,000 items of mostly plastic litter currently in the process of being mobilised from the streams into the Manawatu River.

The significant difference in reported litter rates between the land-based survey (30.5 items/1,000 m^2) and surveyed waterways (2,680 items/1,000 m^2) may be attributable to waterways being the funnel for litter to the ocean, different methods, and different regions surveyed. Further research to measure and understand plastic pollution processes in Aotearoa New Zealand is necessary.

FURTHER RESEARCH TO MEASURE AND UNDERSTAND PLASTIC POLLUTION PROCESSES IN AOTEAROA NEW ZEALAND IS NECESSARY

[639] Further details of the methodology used for the Palmy Plastic Pollution Challenge are available at: https://drive.google.com/file/d/1qZzdhpuqrs7_Pui4RzLR6_hyGSq2BEkE/view

5.9.3 Marine-based plastic pollution

The marine environment is the ultimate repository for plastic waste – quantifying the amount of marine plastic pollution and identifying sources and routes of plastic debris to the ocean is critical. Modelling of how marine pollution travels from its point of origin and moves for up to a decade is illustrated in the Plastic Adrift resource.[640] However, it is difficult to understand the scale of plastic litter that comes from mismanaged waste in Aotearoa New Zealand as opposed to that which reaches our shores from plastic leaked into the environment overseas because marine plastic debris shifts with wind and ocean currents. A tool to model ocean currents being developed by researchers at the Cawthron Institute as part of the Sustainable Seas National Science Challenge will help address these issues.[641]

Plastic pollution from marine-based industry

As outlined in Section 2.4.4, the UNEP estimates at least 640,000 tonnes of fishing gear are lost every year.[642] While there are no data quantifying the amount of ocean plastics attributed to mismanagement of waste from Aotearoa New Zealand, there is evidence that suggests that some of the waste comes from our shores or offshore activities.

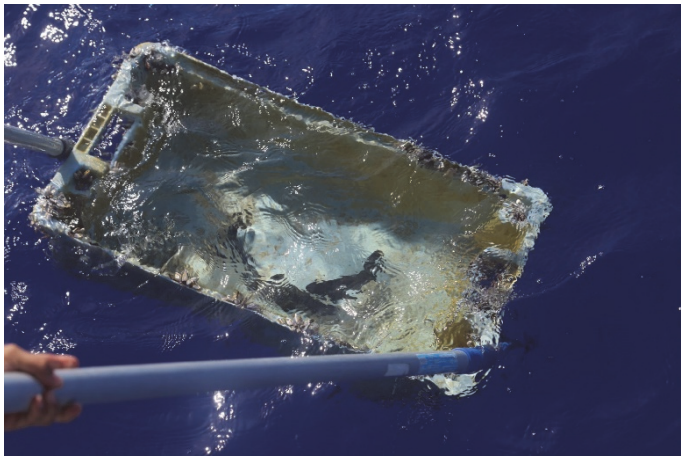


Figure 70 Example of plastic waste from a New Zealand fisheries company found in the ocean. Source: Algalita Marine Research and Education South Pacific.

US mariner, Captain Charles Moore, first described the phenomenon of the oceanic gyres accumulating plastic in 1997. Ocean gyres are slowly churning eddies of plastic 'smog' covering areas bigger than many countries. Two of the five gyres are in the Pacific Ocean – one off the coast of California and the other west of Chile. While it may seem these are far enough from Aotearoa New Zealand's shores to be 'not our problem', the findings of a 2016/2017 expedition by Algalita Marine Research and Education to the South Pacific Sub-Tropical Gyre to the southern Pacific gyre reminds us otherwise.[643]

In their studies of plastic in ocean gyres, Algalita Marine Research and Education South Pacific identified fish bins belonging to New Zealand seafood companies (see Figure 70). At sea, the researchers collected 1 bin from Talleys Group Limited and 1 bin of unknown brand, but identified as being manufactured in New Zealand. The researchers were shown 24 bins by two people that had washed ashore on Rapa Nui. Of the bins found, 18 were from identifiable New Zealand and Australian companies.

[640] The Plastic Adrift resource was developed through a collaboration between the Imperial College London, Utrecht Univeristy and Australian Research Council's Centre of Excellence for Climate System Science and is available at http://plasticadrift.org/

[641] More information available at: https://sustainableseaschallenge.co.nz/programmes/managed-seas/interactive-tools-app

[642] G. Macfadyen, T. Huntington, R. Cappell, Abandoned, lost or otherwise discarded fishing gear. UNEP Regional Seas Reports and Studies No. 185; FAO Fisheries and Aquaculture Technical Paper, No. 523. Rome, UNEP/FAO, 2009.

[643] Further details about the Algalita Marine Research and Education South Pacific available at: https://www.algalitasouthpacific.com/

Table 32 Australian and New Zealand fisheries companies with bins found by Algalita Marine Research and Education South Pacific

Company	Number of bins
Unidentifiable	6
Talley's	4
Deep Cove Fisheries	4
Sanford	3
United Fisheries	2
Bluewater Products Dunedin	1
Dallington Fish Supply Christchurch	1
Whitecloud Seafoods Christchurch	1
Skeggs Foods Nelson	1
RF McLaughlin and Consolidated Fishermen Australia	1

This study does not identify the proportion of ocean waste that comes from our shores, but indicates that emphasis must be placed on quantifying the scale of marine plastic pollution from offshore activities, and identifying the key sources or activities (e.g. lost gear), in order to support activitites to reduce plastic mismanagement during offshore activities. It highlights the need to consider the fisheries industry when rethinking plastics in Aotearoa New Zealand (as discussed in Section 2.4.4).

Plastic ocean debris

Several studies have identified plastic pollution in the marine environment around Aotearoa New Zealand. Floating consumer and industrial plastics were identified in the Hauraki Golf during trawls undertaken between July to September 2008 and consisted of colours and lengths likely to be mistaken as food items for small to medium seabirds.[644] Sea Cleaners, who have been operating and collecting data on volumes of waste in Aotearoa New Zealand's waters, have removed over 8.8 million litres of rubbish from the water, including plastics. The organisation currently removes approximately 160,000 litres per month.

Marine microplastics

Globally, it is estimated that as many as 51 trillion microplastic particles — 500 times more than the stars in our galaxy — litter our oceans and seas.[645] The remoteness and relatively low population density of Aotearoa New Zealand may be thought to result in low levels of marine microplastic pollution. However, levels have been shown to be independent of population density in other areas.[646]

Eriksen et al. modelled levels of plastic, including microplastic, in surface waters around the globe, estimating a minimum of 5 trillion particles weighing over 250,000 tonnes, of which 35,500 tonnes were microplastic.[647] The level of microplastic pollution in the marine environment around Aotearoa New Zealand is currently poorly understood and levels within surface waters have not been examined.

[644] Young et al., "Plastic Debris and Seabird Presence in the Hauraki Gulf, New Zealand," *New Zealand Journal of Marine and Freshwater Research* 44, no. 3 (2010)
[645] UN Oceans Conference Factsheet https://sustainabledevelopment.un.org/content/documents/Ocean_Factsheet_Pollution.pdf
[646] Hirai et al., "Organic Micropollutants in Marine Plastics Debris from the Open Ocean and Remote and Urban Beaches," *Marine Pollution Bulletin* 62, no. 8 (2011)
[647] Eriksen et al., "Plastic Pollution in the World's Oceans: More Than 5 Trillion Plastic Pieces Weighing over 250,000 Tons Afloat at Sea," *PLOS ONE* 9, no. 12 (2014)

In 1977 and 1978, Gregory identified the wide distribution of preproduction plastic pellets (nurdles) around Aotearoa New Zealand.[648] These pellets were found in highest densities around main population centres (Auckland, Wellington and Christchurch), but were also found in remote areas. More recently, work as been carried out looking at the density of nurdle pellets in Wellington Harbour by Algalita Marine Research and Education South Pacific, but the findings have not yet been published.

Assessment of coastal sediment microplastics was carried out for beaches around Christchurch. A range of different morphologies and polymer types were identified.[649] Pellets and fragments were identified, and fibres were disregarded in this study. The predominant polymer types were PS (#6) (55%), PE (polyethylene) (21%) and PP (#5) (11%).

An assessment of 29 Auckland beaches and waterways identified microplastic particles in most samples, with 90% of microplastics being fibres. Of these, about 1/3 were plant-based, such as cellulose or regenerated cellulose like rayon. The other main sources of fibres were PE (polyethylene), PET (#1) and PP (#5).[650]

There is even less known about the levels of microplastics within biota (the impacts of microplastic pollution on biota were discussed in Section 4.16). As mentioned earlier, a recent local study identified zero to 1.5 microplastic particles per green-lipped mussel.[651] Another recent study looked at plastics within the guts of food species finfish from the South Pacfic region, including some samples from Aotearoa New Zealand water.[652] Plastic ingestion rates were found to be comparative with global ingestion rates. Microplastic characteristics included fibres, film and fragments, and represented a range of polmer types, including PVC (#3), PP (#5), Rayon, PE and PES (polyethersulfone). The majority of polyester and rayon microplastics were fibres, consistent with the high level of both these in clothing and resulting wastewater discharged to the marine environment. Vertical habitat differences (pelagic vs benthopelagic) were found to correlate with the levels of microplastics within the stomachs of the fish.

Even less is known about the levels of microplastics in Aotearoa New Zealand's freshwater systems. A 2019 study examined the levels and types of microplastics streams in Auckland, across a gradient of urbanisation.[653] All streams were found to contain microplastics similar to levels found in large systems. Levels weren't related to population density, and local-scale factors are thought to have a greater influence on microplastic abundance than catchment-scale factors.

[648] Gregory, "Plastic Pellets on New Zealand Beaches," *Marine Pollution Bulletin* 8, no. 4 (1977);Gregory, "Accumulation and Distribution of Virgin Plastic Granules on New-Zealand Beaches," *New Zealand Journal of Marine and Freshwater Research* 12, no. 4 (1978)
[649] Clunies-Ross et al., "Synthetic Shorelines in New Zealand? Quantification and Characterisation of Microplastic Pollution on Canterbury's Coastlines," *New Zealand Journal of Marine and Freshwater Research* 50, no. 2 (2016)
[650] Kate Parker, "Turning the Tide on Plastic Microparticles", 2019
[651] Webb et al., "Microplastics in the New Zealand Green Lipped Mussel Perna Canaliculus,"
[652] Markic et al., "Double Trouble in the South Pacific Subtropical Gyre: Increased Plastic Ingestion by Fish in the Oceanic Accumulation Zone,"
[653] Dikareva et al., "Microplastic Pollution in Streams Spanning an Urbanisation Gradient," *Environmental Pollution* 250 (2019)

5.9.4 Case study: Litter Intelligence

Sustainable Coastlines developed Litter Intelligence – a citizen science-based initiative to measure litter on Aotearoa New Zealand's coastlines and collate data in a national coastal litter database.[654] Following a standardised method based on international best practice (UNEP/IOC guidelines on surveying and monitoring of marine litter[655]), citizen scientists survey a coastal site and record the type and weight of each piece of litter found. The data meets Statistics NZ Tier 1 data standards, meaning it can feed into government environmental reporting.[656] Of note, items less than 5 mm in diameter are not recorded, so the findings do not quantify the scale of microplastic pollution. The project is ongoing, with surveys repeated quarterly at the same site, and data are updated in realtime at litterintelligence.org. Over the coming years, the national database will be able to inform and measure the impacts of policy changes and public education campaigns. A snapshot of litter intellegence data as of October 2019 is shown in Figure 71. Single-use plastics dominate the plastic litter items collected from coastal cleanups in Aotearoa New Zealand.

Figure 71 A snapshot of beach clean-up data from Litter Intelligence

SINGLE-USE PLASTICS DOMINATE THE PLASTIC LITTER ITEMS COLLECTED FROM COASTAL CLEANUPS IN AOTEAROA NEW ZEALAND

[654] Further details about Sustainable Coastlines, including data collection methodology are available at: http://sustainablecoastlines.org/
[655] The United Nations Environment Programme (UNEP) and Intergovernmental Oceanographic Commission (IOC) developed guidelines to assist and standardise efforts to monitor and assess marine litter, available at: https://wedocs.unep.org/bitstream/handle/20.500.11822/13604/rsrs186.pdf?sequence=1andisAllowed=y
[656] Data from Litter Intelligence was included in the 'Our marine environment 2019' report from the Ministry for the Environment https://www.mfe.govt.nz/node/25697

5.9.5 Airborne plastic pollution

These has been less investigation into the presence of microplastics in the air and how far it can travel in the atmosphere. A growing body of evidence shows that microplastics are present in the air, in both densely populated city and remote mountain environments, and can travel a distance up to 95 km.[657]

5.9.6 Knowledge gaps

There are significant gaps in our understanding of the scale of plastic leakage into our land and marine environments, for both micro- and macroplastics, as well as the impacts of these (as discussed in Section 4.22).

Several Aotearoa New Zealand-specific studies are underway to expand our understanding of plastics in the environment, but data is not yet available. These include:

- Analysing plastic pollution at a river in Wellington[658]
- Fisheries New Zealand study underway to quantify plastic particles in plankton sample[659]
- Student project investigating microplastics in freshwater sediments and road dust[660]
- Research on how local waste management practices influence plastics found on beaches as part of a national study of 41 east coast beaches.

5.10 Recommendations

There is a need for a national coordinated approach to data collection on plastics, building on previous calls for this from by SBN [661], WasteMINZ [662] and Greenpeace. [663] This is addressed by the suite of recommendations within recommendations 2 and 6.

Key considerations for implementing these recommendations:

- Alignment to and connectivity with international data collection frameworks could guide data collection efforts (note: Sustainable Coastlines' methodology aligns UNEP/IOC guidelines on surveying and monitoring of marine litter[664]; Keep New Zealand Beautiful's methodology is based on global methods, including UNEP guidelines).
- Data collection can be developed to meet the needs of pacts and pledges, including the NZ Plastic Packaging Declaration,[665] New Plastics Economy Global Commitment,[666] UNSDGs[667] and the Basel Convention[668]
- Ongoing local efforts could be drawn on and built on, including:

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[657] Dris et al., "Synthetic Fibers in Atmospheric Fallout: A Source of Microplastics in the Environment?," *Marine Pollution Bulletin* 104, no. 1-2 (2016); Cai et al., "Characteristic of Microplastics in the Atmospheric Fallout from Dongguan City, China: Preliminary Research and First Evidence," *Environmental Science and Pollution Research* 24, no. 32 (2017); Allen et al., "Atmospheric Transport and Deposition of Microplastics in a Remote Mountain Catchment," *Nature Geoscience* 12, no. 5 (2019)

[658] Further details of the research project underway at NIWA analyzing plastic pollution processes in rivers are available at: https://www.niwa.co.nz/freshwater-and-estuaries/research-projects/plastic-pollution-processes-in-rivers

[659] See: https://www.parliament.nz/resource/en-NZ/52SCEN_EVI_77896_784/f7982e48f202667ec63823ff7e29f6d722df70ef

[660] Supervised by Sally Gaw at the University of Canterbury

[661] Circular Economy Accelerator Sustainable Business Network, "New Zealand's Plastic Packaging System, an Initial Circular Economy Diagnosis", 2018

[662] See: https://www.wasteminz.org.nz/projects/national-waste-data-framework-project/

[663] Blumhardt, "Implementing the Plastic-Free New Zealand Action Plan", 2019

[664] The United Nations Environment Programme (UNEP) and Intergovernmental Oceanographic Commission (IOC) developed guidelines to assist and standardise efforts to monitor and assess marine litter. Cheshire, "Unep/Ioc Guidelines on Survey and Monitoring of Marine Litter", 2009

[665] The New Zealand Plastic Packaging Declaration of June 2018 was a pledge by 12 multinational and several local businesses to use 100% reusable, recyclable or compostable packaging in NZ operations by 2025.

[666] The New Plastics Economy Global Commitment is led by the Ellen MacArthur Foundation in collaboration with the UN Environment and has been signed by the Ministry for the Environment and many multinationals More information is available at: https://newplasticseconomy.org/projects/global-commitment

[667] UN General Assembly, "Transforming Our World: The 2030 Agenda for Sustainable Development September 25, 2015", 2016

[668] The amendment to the Basel Convention to restrict waste plastic being shipped from developed to developing countries was signed by 187 countries and will begin to be enforced in 2020. Holden, "Nearly All Countries Agree to Stem Flow of Plastic Waste into Poor Nations,"

- National Waste Data Framework[669]
- GS1 supply chain database[670]
- Rural waste surveys by GHD[671]
- Agrecovery[672] and Plasback[673] schemes
- Unitec study to quantify plastics in construction
- Local council waste assessments
- Litter Intelligence (Sustainable Coastlines)[674]
- Keep New Zealand Beautiful litter audits[675]
- Sea Cleaners data collection[676]
- NIWA study analysing pollution processes in rivers[677]
- Marine microplastic research[678]
- GESAMP ocean plastic monitoring guidelines[679]
- Operation Clean Sweep®[680]
- Algorithms and data created by Crunch & Flourish[681]

- Some councils (e.g. Northland Regional Council) are using the Sustainable Coastlines' Litter Intelligence framework as part of their environmental monitoring and other councils could follow suit and other groups (Raglan Citizen Scientist Beach Project) are building on this to also measure microplastics.

[669] Details of the National Waste Data Framework, including all published reports, are available at: https://www.wasteminz.org.nz/projects/national-waste-data-framework-project/
[670] Details of the GS1 supply chain database are available at: https://www.gs1nz.org/
[671] GHD, Non-natural rural waste: Site survey data analysis (2013), prepared for Environment Canterbury Regional Council; Available at: https://api.ecan.govt.nz/TrimPublicAPI/documents/download/1851763 and [671] GHD, Rural waste surveys data analysis: Waikato and Bay of Plenty (2014), prepared for Waikato Regional Council ; Available at: http://www.waikatoregion.govt.nz/assets/PageFiles/30542/TR201455.pdf
[672] Details of the Agrecovery rural recycling programme are available at: https://www.agrecovery.co.nz/
[673] https://plasback.co.nz/about/
[674] Further details about Sustainable Coastlines' Litter Intelligence project, including data collection methodology are available at: https://litterintelligence.org
[675] https://www.knzb.org.nz/resources/research/nla/
[676] Sea Cleaners has primarily collected data on location, volumes and hours of rubbish collected at sea. More information is available at: https://seacleaners.com/
[677] Further details of the research project underway at NIWA analyzing plastic pollution processes in rivers is available at: https://www.niwa.co.nz/freshwater-and-estuaries/research-projects/plastic-pollution-processes-in-rivers
[678]Further details of a collaborative research project on microplastics in New Zealand are available at: https://www.esr.cri.nz/home/about-esr/media-releases/esr-microplastics-work-wins-multi-million-dollar-funding/
[679] The Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection have developed a set of publically available guidelines for monitoring plastics and microplastics in the oceans, further detail available at: http://www.gesamp.org/news/how-to-monitor-plastics-in-the-oceans
[680] More information about the Operation Clean Sweep® initiative in New Zealand is available at: http://www.plastics.org.nz/environment/marine-litter/operation-clean-sweep
[681] More information available at: https://www.crunchandflourish.com/

Appendices

All appendices are available online at www.pmcsa.ac.nz/our-projects/plastics.

- Appendix 1: The United Nations Sustainable Development Goals
- Appendix 2: Examples of plastics/waste resources on the Science Learning Hub
- Appendix 3: Current labelling and categorisation approaches for plastics used in Aotearoa New Zealand
- Appendix 4: Modern Landfill operational standards
- Appendix 5: Life cycle assessment (LCA)
- Appendix 6: Plastics research projects in Aotearoa New Zealand
- Appendix 7: Tools to support enactment of Māori knowledge systems in environment
- Appendix 8: Import data
- Appendix 9: Imported synthetic textiles
- Appendix 10: Export data
- Appendix 11: Material flows analysis of PET bottles
- Appendix 12: Rural waste
- Appendix 13: Non-municipal landfill
- Appendix 14: Best practice data collection for plastics

References

Air New Zealand. "Air New Zealand Doubles Down on Plastic Waste Reduction", press release, 8 July 2019, http://www.scoop.co.nz/stories/BU1907/S00194/air-new-zealand-doubles-down-on-plastic-waste-reduction.htm

Al-Sid-Cheikh, Rowland, Stevenson, Rouleau, Henry, and Thompson. "Uptake, Whole-Body Distribution, and Depuration of Nanoplastics by the Scallop Pecten Maximus at Environmentally Realistic Concentrations". *Environmental Science & Technology* 52, no. 24 (2018/12/18 2018): 14480-86

Alaerts, Augustinus, and Van Acker. "Impact of Bio-Based Plastics on Current Recycling of Plastics". *Sustainability* 10, no. 5 (2018): 1487

Allen, Allen, Phoenix, Le Roux, Jimenez, Simonneau, Binet, and Galop. "Atmospheric Transport and Deposition of Microplastics in a Remote Mountain Catchment". *Nature Geoscience* 12, no. 5 (May 2019): 339-+

Amaral-Zettler, Zettler, Slikas, Boyd, Melvin, Morrall, Proskurowski, and Mincer. "The Biogeography of the Plastisphere: Implications for Policy". *Frontiers in Ecology and the Environment* 13, no. 10 (Dec 2015): 541-46

APCO. "Business and Government Unite to Tackle Waste Challenge", press release, 26 September 2018, https://www.packagingcovenant.org.au/news/business-and-government-unite-to-tackle-waste-challenge

Arias-Andres, Klumper, Rojas-Jimenez, and Grossart. "Microplastic Pollution Increases Gene Exchange in Aquatic Ecosystems". *Environmental Pollution* 237 (Jun 2018): 253-61

Ashton, Holmes, and Turner. "Association of Metals with Plastic Production Pellets in the Marine Environment". *Marine Pollution Bulletin* 60, no. 11 (Nov 2010): 2050-55

ASTM International, "Astm D7611/D7611m-18 Standard Practice for Coding Plastic Manufactured Articles for Resin Identification", 2018

Auckland Council, "Auckland Waste Management and Minimisation Plan 2018 ", 2018, https://www.aucklandcouncil.govt.nz/plans-projects-policies-reports-bylaws/our-plans-strategies/topic-based-plans-strategies/environmental-plans-strategies/docswastemanagementplan/auckland-waste-management-minimisation-plan.pdf.

Auckland Council, "Auckland's Waste Assessment 2017." 2017, https://www.aucklandcouncil.govt.nz/plans-projects-policies-reports-bylaws/our-plans-strategies/topic-based-plans-strategies/environmental-plans-strategies/docswastemanagementplan/waste-assessment-2017.pdf.

Avio, Gorbi, Milan, Benedetti, Fattorini, d'Errico, Pauletto, Bargelloni, and Regoli. "Pollutants Bioavailability and Toxicological Risk from Microplastics to Marine Mussels". *Environmental Pollution* 198 (Mar 2015): 211-22

Bakir, Rowland, and Thompson. "Enhanced Desorption of Persistent Organic Pollutants from Microplastics under Simulated Physiological Conditions". *Environmental Pollution* 185 (Feb 2014): 16-23

Barnes. "Biodiversity: Invasions by Marine Life on Plastic Debris". *Nature* 416, no. 6883 (Apr 2002): 808-09

Barrett. "Kaneka Wins Japan Bioindustry Award 2019 for Seawater Biodegradable Bioplastics", *Bioplastics News*, 7 August 2019

Barry, and Barry. "Life Cycle Assessment and the New Zealand Wine Industry : A Tool to Support Continuous Environmental Improvement : A Thesis Presented in Partial Fulfilment of the Requirements for the Degree of Master of Environmental Management in Life Cycle Management at Massey University, Wellington, New Zealand", Masters, Massey University, 2011

Beaumont, Aanesen, Austen, Börger, Clark, Cole, Hooper, *et al.* "Global Ecological, Social and Economic Impacts of Marine Plastic". *Marine Pollution Bulletin* 142 (2019/05/01/ 2019): 189-95

Besseling, Wang, Lurling, and Koelmans. "Nanoplastic Affects Growth of S. Obliquus and Reproduction of D. Magna". *Environmental Science & Technology* 48, no. 20 (Oct 21 2014): 12336-43

Beyond the Bin, "A Review of the Availability of New Zealand Compost Facilities to Process Compostable Coffee Cupes and Food Packaging." 2017, https://www.recycling.kiwi.nz/files/2015/0051/3024/TPF_CCC_June_17_Compost_Facilities.pdf.

Biermann. "Planetary Boundaries and Earth System Governance: Exploring the Links". *Ecological Economics* 81 (Sep 2012): 4-9

Blumhardt, "Implementing the Plastic-Free New Zealand Action Plan." 2019, https://storage.googleapis.com/planet4-new-zealand-stateless/2019/04/af9deec9-plastic-free-nz-action-plan-policy-final1.pdf.

Boffey. "Ocean Cleanup Device Successfully Collects Plastic for First Time", *The Guardian*, 3 October 2019

Bolch, and de Salas. "A Review of the Molecular Evidence for Ballast Water Introduction of the Toxic Dinoflagellates *Gymnodinium Catenatum* and the *Alexandrium* "Tamarensis Complex" to Australasia". *Harmful Algae* 6, no. 4 (Aug 2007): 465-85

Boren, Morrissey, Muller, and Gemmell. "Entanglement of New Zealand Fur Seals in Man-Made Debris at Kaikoura, New Zealand". *Marine Pollution Bulletin* 52, no. 4 (Apr 2006): 442-46

Bosker, Bouwman, Brun, Behrens, and Vijver. "Microplastics Accumulate on Pores in Seed Capsule and Delay Germination and Root Growth of the Terrestrial Vascular Plant Lepidium Sativum". *Chemosphere* 226 (2019/07/01/ 2019): 774-81

Boston Consulting Group, "A Circular Solution to Plastic Waste." 2019, https://www.bcg.com/Images/BCG-A-Circular-Solution-to-Plastic-Waste-July-2019_tcm9-223960.pdf.

BP. "Bp's New Technology to Enable Circularity for Unrecyclable Pet Plastic Waste", press release, 24 October 2019, https://www.bp.com/en/global/corporate/news-and-insights/press-releases/bp-new-technology-to-enable-circularity-for-unrecyclable-pet-plastic-waste.html

Brandon, Goldstein, and Ohman. "Long-Term Aging and Degradation of Microplastic Particles: Comparing in Situ Oceanic and Experimental Weathering Patterns". *Marine Pollution Bulletin* 110, no. 1 (2016/09/15/ 2016): 299-308

BRANZ, "New Zealand Whole-Buildling Whole-of-Life Framework: Development of Datasheets to Support Building Life Cycle Assessment." 2016, https://www.branz.co.nz/cms_show_download.php?id=31f4b9d029c8524e03843b1cde2ceb6763e14fb7.

Brennecke, Ferreira, Costa, Appel, da Gama, and Lenz. "Ingested Microplastics (>100 Mm) Are Translocated to Organs of the Tropical Fiddler Crab *Uca Rapax*". *Marine Pollution Bulletin* 96, no. 1-2 (Jul 2015): 491-95

Brooks, Wang, and Jambeck. "The Chinese Import Ban and Its Impact on Global Plastic Waste Trade". *Science Advances* 4, no. 6 (Jun 2018)

Brouwer, Picuno, Thoden van Velzen, Kuchta, De Meester, and Ragaert. "The Impact of Collection Portfolio Expansion on Key Performance Indicators of the Dutch Recycling System for Post-Consumer Plastic Packaging Waste, a Comparison between 2014 and 2017". *Waste Management* 100 (2019/12/01/ 2019): 112-21

Brown, and Macfadyen. "Ghost Fishing in European Waters: Impacts and Management Responses". *Marine Policy* 31, no. 4 (2007/07/01/ 2007): 488-504

Browne, Dissanayake, Galloway, Lowe, and Thompson. "Ingested Microscopic Plastic Translocates to the Circulatory System of the Mussel, Mytilus Edulis (L.)". *Environmental Science & Technology* 42, no. 13 (Jul 1 2008): 5026-31

Browne, Galloway, and Thompson. "Microplastic: An Emerging Contaminant of Potential Concern?". *Integrated Environmental Assessment and Management* 3, no. 4 (Oct 2007): 559-61

Browne, Niven, Galloway, Rowland, and Thompson. "Microplastic Moves Pollutants and Additives to Worms, Reducing Functions Linked to Health and Biodiversity". *Current Biology* 23, no. 23 (Dec 2 2013): 2388-92

Buxton, Currey, Lyver, and Jones. "Incidence of Plastic Fragments among Burrow-Nesting Seabird Colonies on Offshore Islands in Northern New Zealand". *Marine Pollution Bulletin* 74, no. 1 (2013/09/15/ 2013): 420-24

Buxton, Currey, Lyver, and Jones. "Incidence of Plastic Fragments among Burrow-Nesting Seabird Colonies on Offshore Islands in Northern New Zealand". *Marine Pollution Bulletin* 74, no. 1 (Sep 2013): 420-24

Cai, Wang, Peng, Tan, Zhan, Tan, and Chen. "Characteristic of Microplastics in the Atmospheric Fallout from Dongguan City, China: Preliminary Research and First Evidence". *Environmental Science and Pollution Research* 24, no. 32 (Nov 2017): 24928-35

Campbell, King, Heppenstall, van Gool, Martin, and Hewitt. "Aquaculture and Urban Marine Structures Facilitate Native and Non-Indigenous Species Transfer through Generation and Accumulation of Marine Debris". *Marine Pollution Bulletin* 123, no. 1 (2017/10/15/ 2017): 304-12

Campbell, Peters, McMains, de Campos, Sargisson, Blackwell, and Hewitt. "Are Our Beaches Safe? Quantifying the Human Health Impact of Anthropogenic Beach Litter on People in New Zealand". *Science of The Total Environment* 651 (2019/02/15/ 2019): 2400-09

Cannon, Lavers, and Figueiredo. "Plastic Ingestion by Fish in the Southern Hemisphere: A Baseline Study and Review of Methods". *Marine Pollution Bulletin* 107, no. 1 (Jun 2016): 286-91

Center for International Environmental Law, "Plastic & Climate: The Hidden Costs of a Plastic Planet ", 2019, https://www.ciel.org/reports/plastic-health-the-hidden-costs-of-a-plastic-planet-february-2019/.

Center for International Environmental Law, "Plastic & Health: The Hidden Costs of a Plastic Planet." 2019.

Chae, and An. "Current Research Trends on Plastic Pollution and Ecological Impacts on the Soil Ecosystem: A Review". *Environmental Pollution* 240 (Sep 2018): 387-95

Chakrabortty. "Secret Report: Biofuel Caused Food Crisis", *The Guardian*, 3 July 2008

Charissa Rujanavech, "Liam - an Innovation Story." 2016, https://www.apple.com/environment/pdf/Liam_white_paper_Sept2016.pdf.

Chen, Pelton, and Smith. "Comparative Life Cycle Assessment of Fossil and Bio-Based Polyethylene Terephthalate (Pet) Bottles". *Journal of Cleaner Production* 137 (Nov 20 2016): 667-76

Cheshire, "Unep/Ioc Guidelines on Survey and Monitoring of Marine Litter." 2009.

Christakis, and Fowler. "Social Contagion Theory: Examining Dynamic Social Networks and Human Behavior". *Stat Med* 32, no. 4 (Feb 20 2013): 556-77

Christensen, Scheuermann, Loeffler, and Helms. "Closed-Loop Recycling of Plastics Enabled by Dynamic Covalent Diketoenamine Bonds". *Nature Chemistry* 11, no. 5 (2019/05/01 2019): 442-48

Chubarenko, Bagaev, Zobkov, and Esiukova. "On Some Physical and Dynamical Properties of Microplastic Particles in Marine Environment". *Marine Pollution Bulletin* 108, no. 1-2 (Jul 15 2016): 105-12

Circular Economy Accelerator Sustainable Business Network, "New Zealand's Plastic Packaging System, an Initial Circular Economy Diagnosis." 2018.

Civancik-Uslu, Puig, Hauschild, and Fullana-i-Palmer. "Life Cycle Assessment of Carrier Bags and Development of a Littering Indicator". *Science of The Total Environment* 685 (2019/10/01/ 2019): 621-30

Clark, Tanner-Smith, and Killingsworth. "Digital Games, Design, and Learning: A Systematic Review and Meta-Analysis". *Review of Educational Research* 86, no. 1 (Mar 2016): 79-122

Clayton. "San Francisco Airport Announces Ban on Sales of Plastic Water Bottles", *The Guardian*, 2 August 2019

Clunies-Ross, Smith, Gordon, and Gaw. "Synthetic Shorelines in New Zealand? Quantification and Characterisation of Microplastic Pollution on Canterbury's Coastlines". *New Zealand Journal of Marine and Freshwater Research* 50, no. 2 (2016/04/02 2016): 317-25

Coca-Cola. "Breakthrough Technology Takes Plastic from the Ocean and Uses It in a Coca-Cola Bottle", press release, 3 October 2019, https://www.businesswire.com/news/home/20191003005139/en/Breakthrough-Technology-Takes-Plastic-Ocean-Coca-Cola-Bottle

Coca-Cola. "Coca-Cola Oceania, Amatil Announce New Recycling Plan", press release, 31 July 2019, http://www.scoop.co.nz/stories/BU1907/S00770/coca-cola-oceania-amatil-announce-new-recycling-plan.htm

Cole, Lindeque, Fileman, Halsband, and Galloway. "The Impact of Polystyrene Microplastics on Feeding, Function and Fecundity in the Marine Copepod Calanus Helgolandicus". *Environmental Science & Technology* 49, no. 2 (Jan 20 2015): 1130-37

Cole, Lindeque, Halsband, and Galloway. "Microplastics as Contaminants in the Marine Environment: A Review". *Marine Pollution Bulletin* 62, no. 12 (Dec 2011): 2588-97

Colmar Brunton, "Better Futures 2019." 2019.

Common Seas. "Plastic Drawdown: A New Approach to Addressing Plastic Pollution from Source to Ocean. Summary for Policy Makers". (2019)

Covec Ltd, "Evaluating the Costs and Benefits of Introducing a Container Deposit System for New Zealand: Summary of Analysis ", 2016, https://www.recycling.kiwi.nz/files/3014/6101/9990/CDS_report_2016.pdf.

Cox, Covernton, Davies, Dower, Juanes, and Dudas. "Human Consumption of Microplastics". *Environmental Science & Technology* 53, no. 12 (2019/06/18 2019): 7068-74

Cozar, Echevarria, Gonzalez-Gordillo, Irigoien, Ubeda, Hernandez-Leon, Palma*, et al.* "Plastic Debris in the Open Ocean". *Proceedings of the National Academy of Sciences of the United States of America* 111, no. 28 (Jul 15 2014): 10239-44

D Grimmond, "Review of Packaging Mass Balance Measurements." 2015, http://www.packaging.org.nz/attachments/docs/review-of-packaging-mass-balance-measurements.pdf.

De Falco, Gentile, Avolio, Errico, Di Pace, Ambrogi, Avella, and Cocca. "Pectin Based Finishing to Mitigate the Impact of Microplastics Released by Polyamide Fabrics". *Carbohydrate Polymers* 198 (2018/10/15/ 2018): 175-80

Dehaut, Cassone, Frère, Hermabessiere, Himber, Rinnert, Rivière*, et al.* "Microplastics in Seafood: Benchmark Protocol for Their Extraction and Characterization". *Environmental Pollution* 215 (8// 2016): 223-33

Department of Conservation, "Mātauranga Whakauka Taiao, Environmental Education for Sustainability." 2017, https://www.doc.govt.nz/Documents/getting-involved/students-and-teachers/environmental-education-for-sustainability-strategy-and-action-plan.pdf.

Derraik. "The Pollution of the Marine Environment by Plastic Debris: A Review". *Marine Pollution Bulletin* 44 (2002): 842-52

Dikareva, and Simon. "Microplastic Pollution in Streams Spanning an Urbanisation Gradient". *Environmental Pollution* 250 (2019/07/01/ 2019): 292-99

Dris, Gasperi, Saad, Mirande, and Tassin. "Synthetic Fibers in Atmospheric Fallout: A Source of Microplastics in the Environment?". *Marine Pollution Bulletin* 104, no. 1-2 (Mar 15 2016): 290-93

Duis, and Coors. "Microplastics in the Aquatic and Terrestrial Environment: Sources (with a Specific Focus on Personal Care Products), Fate and Effects". *Environmental Sciences Europe* 28 (Jan 6 2016)

Durie, "Measuring Māori Wellbeing." 2006, https://treasury.govt.nz/sites/default/files/2007-09/tgls-durie.pdf.

Eckert, Di Cesare, Kettner, Arias-Andres, Fontaneto, Grossart, and Corno. "Microplastics Increase Impact of Treated Wastewater on Freshwater Microbial Community". *Environmental Pollution* 234 (2018/03/01/ 2018): 495-502

Eich, Mildenberger, Laforsch, and Weber. "Biofilm and Diatom Succession on Polyethylene (Pe) and Biodegradable Plastic Bags in Two Marine Habitats: Early Signs of Degradation in the Pelagic and Benthic Zone?". *Plos One* 10, no. 9 (Sep 2015)

Elf, Gatersleben, and Christie. "Facilitating Positive Spillover Effects: New Insights from a Mixed-Methods Approach Exploring Factors Enabling People to Live More Sustainable Lifestyles". *Front Psychol* 9 (2018): 2699

Elizabeth Sinclair. "We Organised a Conference for 570 People without Using Plastic. Here's How It Went", *The Conversation*, 10 July 2019

Ellen MacArthur Foundation, "The New Plastics Economy Global Commitment ", 2017, https://newplasticseconomy.org/projects/global-commitment.

Ellen MacArthur Foundation, "New Plastics Economy Global Commitment June 2019 Report." 2019, https://www.newplasticseconomy.org/assets/doc/GC-Report-June19.pdf.

Ellen MacArthur Foundation, "A New Textiles Economy: Redesigning Fashion's Future ", 2017, https://www.ellenmacarthurfoundation.org/publications/a-new-textiles-economy-redesigning-fashions-future.

Ellen MacArthur Foundation, "Reuse - Rethinking Packaging." 2019, https://www.ellenmacarthurfoundation.org/assets/downloads/Reuse.pdf.

Envision, "The Incentive to Recycle: The Case for a Container Deposit System in New Zealand ", 2015, https://static1.squarespace.com/static/539a5fdee4b09201c768daef/t/59f79b546926704f354d8cee/1509399400468/The+InCENTive+to+Recycle_full+report.pdf.

Eriksen. "Polynesian Sailing Vessels Are Being Used to Clean up Microplastics." *National Geographic*, 7 June 2018 2018

Eriksen, Damgaard, Boldrin, and Astrup. "Quality Assessment and Circularity Potential of Recovery Systems for Household Plastic Waste". *Journal of Industrial Ecology* 23, no. 1 (2019): 156-68

Eriksen, Lebreton, Carson, Thiel, Moore, Borerro, Galgani, Ryan, and Reisser. "Plastic Pollution in the World's Oceans: More Than 5 Trillion Plastic Pieces Weighing over 250,000 Tons Afloat at Sea". *PLOS ONE* 9, no. 12 (2014): e111913

Eunomia Research & Consulting Ltd, "Investigating Options for Reducing Releases in the Aquatic Environment of Microplastics Emitted by Products." 2018, https://www.eunomia.co.uk/reports-tools/investigating-options-for-reducing-releases-in-the-aquatic-environment-of-microplastics-emitted-by-products/.

Eunomia Research & Consulting Ltd, "National Resource Recovery Project – Situational Analysis Report." 2018, https://www.mfe.govt.nz/sites/default/files/media/Waste/national-resource-recovery-project-redacted.pdf.

Eunomia Research & Consulting Ltd, "The New Zealand Waste Disposal Levy: Potential Impacts of Adjustments to the Current Levy Rate and Structure." 2017, https://www.wasteminz.org.nz/wp-content/uploads/2017/06/NZ-Waste-Disposal-Levy-Final-Report-Eunomia-30-May-2017.pdf.

Eunomia Research & Consulting Ltd, "A Wasted Opportunity - Using the Waste Disposal Levy to Create Economic and Environmental Advantage in Aotearoa New Zealand." 2017.

European Bioplastics, "Bio-Based Building Blocks and Polymers: Global Capacities and Trends 2016–2021." 2017, http://bio-based.eu/media/edd/2017/03/17-02-Bio-based-Building-Blocks-and-Polymers-short-version.pdf.

European Chemicals Agency, https://echa.europa.eu/mapping-exercise-plastic-additives-initiative

European Commission. "European Parliament Votes for Single-Use Plastics Ban", press release, 18 January 2019, https://ec.europa.eu/environment/efe/news/european-parliament-votes-single-use-plastics-ban-2019-01-18_en

European Commission, "A European Strategy for Plastics in a Circular Economy." 2019, https://ec.europa.eu/environment/circular-economy/pdf/plastics-strategy-brochure.pdf.

Farrell, and Nelson. "Trophic Level Transfer of Microplastic: Mytilus Edulis (L.) to Carcinus Maenas (L.)". *Environmental Pollution* 177 (2013/06/01/ 2013): 1-3

Farrelly. "Why Municipal Waste-to-Energy Incineration Is Not the Answer to Nz's Plastic Waste Crisis", *The Conversation*, 13 November 2019

Farrelly, and Tucker. "Action Research and Residential Waste Minimisation in Palmerston North, New Zealand". *Resources, Conservation and Recycling* 91 (2014/09/01/ 2014): 11-26

Faury, Saulnier, Thompson, Gay, Swings, and Le Roux. "*Vibrio Crassostreae* Sp Nov., Isolated from the Haemolymph of Oysters (*Crassostrea Gigas*)". *International Journal of Systematic and Evolutionary Microbiology* 54 (Nov 2004): 2137-40

Ferrara, and De Feo. "Life Cycle Assessment Application to the Wine Sector: A Critical Review". *Sustainability* 10, no. 2 (2018): 395

Fisher. "How Lego Figures and Rubber Ducks Reveal Ocean Secrets", *BBC*, 22 July 2014

Flaws. "Mushroom Company to Make Its Own Packaging - from Mushrooms ", *Stuff*, 13 June 2019

Flaws. "Time for Piecemeal Plastic Waste Solutions Has Passed, Says the Warehouse", *Stuff*, 28 July 2019

Forest & Bird. "Nz Seas Worst in World for Seabirds Eating Plastic", press release, 2 July 2018

Forum for Circular Plastic Packaging under the Danish Plastics Federation, "Reuse and Recycling of Plastic Packaging for Private Use." 2018.

Fossi, Panti, Guerranti, Coppola, Giannetti, Marsili, and Minutoli. "Are Baleen Whales Exposed to the Threat of Microplastics? A Case Study of the Mediterranean Fin Whale (Balaenoptera Physalus)". *Marine Pollution Bulletin* 64, no. 11 (Nov 2012): 2374-79

Foster. "G20 to Tackle Ocean Plastic Waste as Petrochemical Producers Expand in Asia", *Reuters*, 13 June 2019

Fox. "Just 10% of U.S. Plastic Gets Recycled. A New Kind of Plastic Could Change That", *Science*, 22 April 2019

Fresán, Errendal, Craig, and Sabaté. "Does the Size Matter? A Comparative Analysis of the Environmental Impact of Several Packaged Foods". *Science of The Total Environment* 687 (2019/10/15/ 2019): 369-79

Gallo, Fossi, Weber, Santillo, Sousa, Ingram, Nadal, and Romano. "Marine Litter Plastics and Microplastics and Their Toxic Chemicals Components: The Need for Urgent Preventive Measures". *Environmental sciences Europe* 30, no. 1 (2018): 13-13

Gestoso, Cacabelos, Ramalhosa, and Canning-Clode. "Plasticrusts: A New Potential Threat in the Anthropocene's Rocky Shores". *Science of The Total Environment* 687 (2019/10/15/ 2019): 413-15

Geyer, Jambeck, and Law. "Production, Use, and Fate of All Plastics Ever Made". *Science Advances* 3, no. 7 (Jul 2017)

Gibb. "Praise for Public Plastic Recycling Trial", press release, 26 February 2019, https://www.odt.co.nz/business/praise-public-plastic-recycling-trial

Gilman. "Status of International Monitoring and Management of Abandoned, Lost and Discarded Fishing Gear and Ghost Fishing". *Marine Policy* 60 (2015/10/01/ 2015): 225-39

Godoy, and Stockin. "Anthropogenic Impacts on Green Turtles Chelonia Mydas in New Zealand". *Endangered Species Research* 37 (2018): 1-9

Golden Bay. "Golden Bay 1st Community to Be Free of Plastic Bags", press release, 3 January 2005, http://www.scoop.co.nz/stories/AK0501/S00002/goldenbay-1st-community-to-be-free-of-plastic-bags.htm

Goldstein, and Cialdini. "Using Social Norms as a Lever of Social Influence". *Science of Social Influence: Advances and Future Progress* (2007): 167-91

Goldstein, Rosenberg, and Cheng. "Increased Oceanic Microplastic Debris Enhances Oviposition in an Endemic Pelagic Insect". *Biology Letters* 8, no. 5 (Oct 2012): 817-20

Government of Canada. "Canada to Ban Harmful Single-Use Plastics and Hold Companies Responsible for Plastic Waste", press release, 10 June 2019, https://pm.gc.ca/en/news/news-releases/2019/06/10/canada-ban-harmful-single-use-plastics-and-hold-companies-responsible

Graham, and Thompson. "Deposit- and Suspension-Feeding Sea Cucumbers (Echinodermata) Ingest Plastic Fragments". *Journal of Experimental Marine Biology and Ecology* 368, no. 1 (Jan 2009): 22-29

Gregory. "Accumulation and Distribution of Virgin Plastic Granules on New-Zealand Beaches". *New Zealand Journal of Marine and Freshwater Research* 12, no. 4 (1978): 399-414

Gregory. "Environmental Implications of Plastic Debris in Marine Settings-Entanglement, Ingestion, Smothering, Hangers-on, Hitch-Hiking and Alien Invasions". *Philosophical Transactions of the Royal Society B-Biological Sciences* 364, no. 1526 (Jul 2009): 2013-25

Gregory. "Plastic Pellets on New Zealand Beaches". *Marine Pollution Bulletin* 8, no. 4 (1977/04/01/ 1977): 82-84

Group of Chief Scientific Advisors European Comission, "Environmental and Health Risks of Microplastic Pollution." 2019, https://ec.europa.eu/info/sites/info/files/research_and_innovation/groups/sam/ec_rtd_sam-mnp-opinion_042019.pdf.

Haider, Volker, Kramm, Landfester, and Wurm. "Plastics of the Future? The Impact of Biodegradable Polymers on the Environment and on Society". *Angewandte Chemie-International Edition* 58, no. 1 (Jan 2 2019): 50-62

Hamilton City Council. "Hamiltonians Urged to Make a Plastic Free Pledge This July", press release, 1 July 2019, http://www.scoop.co.nz/stories/AK1907/S00031/hamiltonians-urged-to-make-a-plastic-free-pledge-this-july.htm

Harmsworth, and Awatere. "Indigenous Maori Knowledge and Perspectives of Ecosystems". *Ecosystem Services in New Zealand: Conditions and Trends* (2013): 274-86

Harré. *Psychology for a Better World: Working with People to Save the Planet.* Auckland: Auckland University Press, 2018.

Hauser. *Moral Minds: The Nature of Right and Wrong.* New York: HarperCollins 2006.

He, Chen, Shao, Zhang, and Lü. "Municipal Solid Waste (Msw) Landfill: A Source of Microplastics? -Evidence of Microplastics in Landfill Leachate". *Water Research* 159 (2019/08/01/ 2019): 38-45

Hernandez, Xu, Larsson, Tahara, Maisuria, and Tufenkji. "Plastic Teabags Release Billions of Microparticles and Nanoparticles into Tea". *Environmental Science & Technology* (2019/09/25 2019)

Hirai, Takada, Ogata, Yamashita, Mizukawa, Saha, Kwan*, et al.* "Organic Micropollutants in Marine Plastics Debris from the Open Ocean and Remote and Urban Beaches". *Marine Pollution Bulletin* 62, no. 8 (Aug 2011): 1683-92

Holden. "Nearly All Countries Agree to Stem Flow of Plastic Waste into Poor Nations", *The Guardian*, 11 May 2019

Hon Eugenie Sage. "New Zealand Signs Global Declaration to Cut Plastic Waste", press release, 20 October 2018, https://www.beehive.govt.nz/release/new-zealand-signs-global-declaration-cut-plastic-waste

Hon Eugenie Sage. "Plan to Recharge Recycling", press release, 10 May 2019, https://www.beehive.govt.nz/release/plan-recharge-recycling

Hon Eugenie Sage. "Work Underway for Beverage Container Return Scheme", press release, 25 September 2019, https://www.beehive.govt.nz/release/work-underway-beverage-container-return-scheme

Honey. "Why I'm Taking on My School Examiners over Their Plastic Habit", *The Spinoff*, 23 August 2019

Huber, Bickerton, Müssig, Pang, and Staiger. "Solvent Infusion Processing of All-Cellulose Composite Materials". *Carbohydrate Polymers* 90, no. 1 (2012/09/01/ 2012): 730-33

Huffadine. "Use Your Own Cup: Tackling Single-Use Culture One Cup at a Time", *Radio New Zealand*, 18 February 2019

Hutchings, "Enhancing Māori Agribusiness through Kaitiakitanga Tools." 2017.

Illes. "What the World Can Learn from Māori Thinking." *Medium*, 29 May 2019 2019

Infrastructure, "Biobased Plastics in a Circular Economy: Policy Suggestions for Biobased and Biobased Biodegradable Plastics." 2017.

Jabbar, and Felicia. "Gameplay Engagement and Learning in Game-Based Learning: A Systematic Review". *Review of Educational Research* 85, no. 4 (Dec 2015): 740-79

Jambeck, Geyer, Wilcox, Siegler, Perryman, Andrady, Narayan, and Law. "Plastic Waste Inputs from Land into the Ocean". *Science* 347, no. 6223 (Feb 13 2015): 768-71

Jolly. "Tesco Promises to Ban Brands That Use Excessive Packaging", *The Guardian*, 22 August 2019

Jonhson. "Seeking a Greener Option for Film Recycling", *Plastics News*, 7 March 2019

Jull, Bier, Künnemeyer, and Schaare. "Classification of Recyclables Using Laser-Induced Breakdown Spectroscopy for Waste Management". *Spectroscopy Letters* 51, no. 6 (2018/07/03 2018): 257-65

Kang, Zhou, Duan, Sun, Ao, and Wang. "Degradation of Cosmetic Microplastics Via Functionalized Carbon Nanosprings". *Matter* (2019/07/31/ 2019)

Karami, Golieskardi, Choo, Larat, Galloway, and Salamatinia. "The Presence of Microplastics in Commercial Salts from Different Countries". *Scientific Reports* 7 (Apr 6 2017)

Kate Parker, "Turning the Tide on Plastic Microparticles." 2019.

Kawai, Kawabata, and Oda. "Current Knowledge on Enzymatic Pet Degradation and Its Possible Application to Waste Stream Management and Other Fields". *Applied Microbiology and Biotechnology* 103, no. 11 (June 01 2019): 4253-68

Kaza, "What a Waste 2.0 : A Global Snapshot of Solid Waste Management to 2050." 2018, https://openknowledge.worldbank.org/handle/10986/30317.

Kealy. "Rheological Analysis of the Degradation of Hdpe During Consecutive Processing Steps and for Different Processing Conditions". *Journal of Applied Polymer Science* 112, no. 2 (2009): 639-48

Keep New Zealand Beautiful, "National Litter Audit." 2019, https://www.knzb.org.nz/wp-content/uploads/2019/10/KNZB-National-Litter-Audit-Report.pdf.

Keep New Zealand Beautiful, "National Litter Behaviour Research." 2018, https://www.litter.org.nz/assets/Uploads/Behaviour-Study/6414f5b4d5/KNZB-Litter-behaviour-report-DRAFT-0.3-Released-3.4.18.pdf.

Kelly, Lant, Kurr, and Burgess. "Importance of Water-Volume on the Release of Microplastic Fibers from Laundry". *Environmental Science & Technology* (2019/08/28 2019)

Keswani, Oliver, Gutierrez, and Quilliam. "Microbial Hitchhikers on Marine Plastic Debris: Human Exposure Risks at Bathing Waters and Beach Environments". *Marine Environmental Research* 118 (2016/07/01/ 2016): 10-19

Kirstein, Kirmizi, Wichels, Garin-Fernandez, Erler, Löder, and Gerdts. "Dangerous Hitchhikers? Evidence for Potentially Pathogenic Vibrio Spp. On Microplastic Particles". *Marine Environmental Research* 120 (2016/09/01/ 2016): 1-8

Koehler, Marx, Broeg, Bahns, and Bressling. "Effects of Nanoparticles in *Mytilus Edulis* Gills and Hepatopancreas: A New Threat to Marine Life?". *Marine Environmental Research* 66, no. 1 (Jul 2008): 12-14

Kurenbach, Gibson, Hill, Bitzer, Silby, Godsoe, and Heinemann. "Herbicide Ingredients Change Salmonella Enterica Sv. Typhimurium and Escherichia Coli Antibiotic Responses". *Microbiology-Sgm* 163, no. 12 (Dec 2017): 1791-801

Lavers, and Bond. "Exceptional and Rapid Accumulation of Anthropogenic Debris on One of the World's Most Remote and Pristine Islands". *Proceedings of the National Academy of Sciences of the United States of America* 114, no. 23 (Jun 6 2017): 6052-55

Lavers, Dicks, Dicks, and Finger. "Significant Plastic Accumulation on the Cocos (Keeling) Islands, Australia". *Scientific Reports* 9 (May 16 2019)

Lavers, Hutton, and Bond. "Clinical Pathology of Plastic Ingestion in Marine Birds and Relationships with Blood Chemistry". *Environmental Science & Technology* (2019/07/15 2019)

Law, and Thompson. "Microplastics in the Seas". *Science* 345, no. 6193 (Jul 2014): 144-45

Lebreton, Slat, Ferrari, Sainte-Rose, Aitken, Marthouse, Hajbane*, et al.* "Evidence That the Great Pacific Garbage Patch Is Rapidly Accumulating Plastic". *Scientific Reports* 8, no. 1 (2018/03/22 2018): 4666

Lewis. "How the New Circular Bio-Economy Could Deal with the Problem of Plastic." *The Listener*, 23 October 2019 2019

Li, Tse, and Fok. "Plastic Waste in the Marine Environment: A Review of Sources, Occurrence and Effects". *Science of the Total Environment* 566 (Oct 1 2016): 333-49

Li, Zhou, Yin, Tu, and Luo. "Uptake and Accumulation of Microplastics in an Edible Plant". *Chinese Science Bulletin* 64, no. 0023-074X (2019): 928

Lobelle, and Cunliffe. "Early Microbial Biofilm Formation on Marine Plastic Debris". *Marine Pollution Bulletin* 62, no. 1 (Jan 2011): 197-200

Local Government NZ. "Eight Important Issues Debated at Lgnz Agm", press release, 25 July 2016, http://www.scoop.co.nz/stories/AK1607/S00696/eight-important-issues-debated-at-lgnz-agm.htm

Local Government NZ. "Move to Put Pressure on Waste Producers Welcomed by Lgnz", press release, 9 August 2019, https://www.lgnz.co.nz/news-and-media/2019-media-releases/move-to-put-pressure-on-waste-producers-welcomed-by-lgnz/

Local Government NZ, "Vulnerable: The Quantum of Local Government Infrastructure Exposed to Sea Level Rise." 2019, https://www.lgnz.co.nz/assets/Uploads/d566cc5291/47716-LGNZ-Sea-Level-Rise-Report-3-Proof-FINAL-compressed.pdf.

Long, Harre, and Atkinson. "Understanding Change in Recycling and Littering Behavior across a School Social Network". *Am J Community Psychol* 53, no. 3-4 (Jun 2014): 462-74

Lopez, Artetxe, Amutio, Alvarez, Bilbao, and Olazar. "Recent Advances in the Gasification of Waste Plastics. A Critical Overview". *Renewable and Sustainable Energy Reviews* 82 (2018/02/01/ 2018): 576-96

Louis A Trembley, "A Review of Microplastics Risk - Implications for Environment Southland." 2019, https://www.envirolink.govt.nz/assets/Envirolink/Reports/1902-ESRC207-A-review-of-microplastics-risk-implications-for-environment-southland-.pdf.

Lush. "First-Ever 'Carbon-Positive' Packaging Made from Cork", press release, 1 August 2019, https://www.springwise.com/innovation/beauty/carbon-positive-packaging-lush-cosmetics

Lwanga, Gertsen, Gooren, Peters, Salanki, van der Ploeg, Besseling, Koelmans, and Geissen. "Incorporation of Microplastics from Litter into Burrows of Lumbricus Terrestris". *Environmental Pollution* 220 (Jan 2017): 523-31

Markic, Niemand, Bridson, Mazouni-Gaertner, Gaertner, Eriksen, and Bowen. "Double Trouble in the South Pacific Subtropical Gyre: Increased Plastic Ingestion by Fish in the Oceanic Accumulation Zone". *Marine Pollution Bulletin* 136 (Nov 2018): 547-64

Markic, Niemand, Bridson, Mazouni-Gaertner, Gaertner, Eriksen, and Bowen. "Double Trouble in the South Pacific Subtropical Gyre: Increased Plastic Ingestion by Fish in the Oceanic Accumulation Zone". *Marine Pollution Bulletin* 136 (2018/11/01/ 2018): 547-64

Marston, "Bio-Derived Polymers and Composites." 2008.

Martijn van Praagh, "Microplastics in Landfill Leachates in the Nordic Countries." 2018, Nordic Council of Ministers 2018

Mattsson, Johnson, Malmendal, Linse, Hansson, and Cedervall. "Brain Damage and Behavioural Disorders in Fish Induced by Plastic Nanoparticles Delivered through the Food Chain". *Scientific Reports* 7, no. 1 (2017/09/13 2017): 11452

McAdam. *Freedom Summer.* New York: Oxford University Press, 1988.

McCullough. "Indonesia to Send Contaminated Recycling Back to Nz", *Radio New Zealand*, 20 September 2019

Mermaids Ocean Clean Wash, "Handbook for Zero Microplastics from Textiles and Laundry." 2019, https://www.oceancleanwash.org/wp-content/uploads/2019/08/Handbook-for-zero-microplastics-from-textiles-and-laundry-developed.pdf.

Miafodzyeva, and Brandt. "Recycling Behaviour among Householders: Synthesizing Determinants Via a Meta-Analysis". *Waste and Biomass Valorization* 4, no. 2 (June 01 2013): 221-35

Ministry for Business, "Energy in New Zealand." 2019, https://www.mbie.govt.nz/dmsdocument/7040-energy-in-new-zealand-2019.

Ministry for Primary Industries, "Situation and Outlook for Primary Industries.", 2017.

Ministry for the Environment, "2011 Users' Guide to the Revised National Environmental Standards for Air Quality." 2014, https://www.mfe.govt.nz/sites/default/files/2011-user-guide-nes-air-quality.pdf.

Ministry for the Environment, "National Resource Recovery Taskforce: New Zealand's Options in Response to Effects Created by the Implementation of the National Sword Policy. Briefing Note." 2019, https://www.mfe.govt.nz/sites/default/files/media/Waste/national-resource-recovery-briefing-note.pdf.

Ministry for the Environment, "Proposed Mandatory Phase out of Single-Use Plastic Shopping Bags: Consulation Document." 2018.

Ministry for the Environment, "Review of the Effectiveness of the Waste Disposal Levy 2017." 2017.

Ministry for the Environment, "Waste Assessments and Waste Management and Minimisation Planning – a Guide for Territorial Authorities." 2015.

Ministry of Education, "He Whakaaro, Educational Insights: How Environmentally Aware Are New Zealand Students? ." 2019, https://www.eonz.org.nz/assets/Resources/Research/He-Whakaaro-How-environmentally-aware-are-New-Zealand-students.pdf.

Ministry of Foreign Affairs and Trade, "He Waka Eke Noa: Towards a Better Future, Together. New Zealand's Progress Towards the Sdgs - 2019." 2019.

Ministry of Foreign Affairs and Trade, "Strategic Intentions 2018-2022." 2018.

Morelle. "Mariana Trench: Deepest-Ever Sub Dive Finds Plastic Bag", *BBC*, 13 May 2019

Murray, and Cowie. "Plastic Contamination in the Decapod Crustacean *Nephrops Norvegicus* (Linnaeus, 1758)". *Marine Pollution Bulletin* 62, no. 6 (Jun 2011): 1207-17

Murray E., and Bronwyn. *National Survey of Pesticides and Emerging Organic Contaminants (Eocs) in Groundwater 2018.* 2019. doi:10.26091/ESRNZ.9937304.v1.

Naeem, Chazdon, Duffy, Prager, and Worm. "Biodiversity and Human Well-Being: An Essential Link for Sustainable Development". *Proceedings of the Royal Society B: Biological Sciences* 283, no. 1844 (2016/12/14 2016): 20162091

Nakashima, Isobe, Kako, Itai, Takahashi, and Guo. "The Potential of Oceanic Transport and Onshore Leaching of Additive-Derived Lead by Marine Macro-Plastic Debris". *Marine Pollution Bulletin* 107, no. 1 (Jun 15 2016): 333-39

National Science Foundation. "Nsf Announces Fy 2020 Efri Topics", press release, 17 April 2019, https://www.nsf.gov/news/news_summ.jsp?cntn_id=298348&org=EFMA

NBC News. "A Mutant Plastic-Eating Enzyme Could Help Solve the World's Waste Problem", 6 June 2018

New Plastics Economy Pioneer Project, "Holygrail: Tagging Packaging for Accurate Sorting and High-Quality Recycling." 2019, http://go.pardot.com/l/110942/2019-05-28/lhts3n.

New Plymouth District Council. "Coffee Beans Add Zing to Zero Waste Journey", press release, 22 March 2019, http://www.scoop.co.nz/stories/AK1903/S00659/coffee-beans-add-zing-to-zero-waste-journey.htm

New Zealand Government. "Minister Announces Multi-Agency Landfill Risk Response", press release, 11 September 2019, https://www.scoop.co.nz/stories/PA1909/S00075/minister-announces-multi-agency-landfill-risk-response.htm

New Zealand Government. "Work Underway for Beverage Container Return Scheme", press release, 25 September 2019, http://www.scoop.co.nz/stories/PA1909/S00214/work-underway-for-beverage-container-return-scheme.htm

New Zealand Government Procurement Branch, "Government Procurement Rules: Rules for Sustainable and Inclusive Procurement." 2019.

Oberbeckmann, Loeder, Gerdts, and Osborn. "Spatial and Seasonal Variation in Diversity and Structure of Microbial Biofilms on Marine Plastics in Northern European Waters". *Fems Microbiology Ecology* 90, no. 2 (Nov 2014): 478-92

Ocean Conservancy, "Stemming the Tide: Land-Based Strategies for a Plastic- Free Ocean." 2017, https://oceanconservancy.org/wp-content/uploads/2017/04/full-report-stemming-the.pdf.

OECD. "Improving Plastics Management". (2018)

OECD, "Municipal Waste Database", 2015

Office of the Prime Minister's Chief Science Advisor, "Antimicrobial Resistance – an Imminent Threat to Aotearoa, New Zealand." 2018, https://www.pmcsa.ac.nz/2018/11/02/antimicrobial-resistance/.

Ogata, Takada, Mizukawa, Hirai, Iwasa, Endo, Mato*, et al.* "International Pellet Watch: Global Monitoring of Persistent Organic Pollutants (Pops) in Coastal Waters. 1. Initial Phase Data on Pcbs, Ddts, and Hchs". *Marine Pollution Bulletin* 58, no. 10 (Oct 2009): 1437-46

Oji Fibre Solutions. "Oji Fibre Solutions Teams up on Plastic Recycling Technology", press release, 2 August 2019, http://business.scoop.co.nz/2019/08/02/oji-fibre-solutions-teams-up-on-plastic-recycling-technology/

Paben. "Facility to Depolymerize up to 88m Pounds of Pet Annually", *Plastics Recycling Update*, 16 October 2019

Packaging Council of New Zealand/Accord Secretariat, "New Zealand Packaging Accord 2004 Year Five Progress Report." 2009.

Packaging Gateway. "Coca-Cola's 100% Plant-Based Bottle",

Paço, Duarte, da Costa, Santos, Pereira, Pereira, Freitas, Duarte, and Rocha-Santos. "Biodegradation of Polyethylene Microplastics by the Marine Fungus Zalerion Maritimum". *Science of The Total Environment* 586 (2017/05/15/ 2017): 10-15

Palm, Reisky, Böttcher, Müller, Michels, Walczak, Berndt*, et al.* "Structure of the Plastic-Degrading Ideonella Sakaiensis Mhetase Bound to a Substrate". *Nature Communications* 10, no. 1 (2019/04/12 2019): 1717

Parliamentary Commissioner for the Environment, "Biodegradable and Compostable Plastics in the Environment." 2018, https://www.pce.parliament.nz/publications/biodegradable-and-compostable-plastics-in-the-environment/biodegradable-and-compostable-plastics-in-the-environment.

Patel. "Mutant Enzyme Gobbles up Plastic", *Anthropocene*, 19 April 2018

Paul Mitchell. "Palmerston North Pipe-Maker Recycling 25 Tonnes of Plastic a Month in New Partnership", *Stuff*, 25 February 2019

Peter Cressey, "Risk Profile: Ciguatoxins in Seafood." 2019.

Plastics Europe. "The Impact of Plastics on Life Cycle Energy Consumption and Greenhouse Gas Emissions in Europe (Summary Report)". (2010)

Prata. "Microplastics in Wastewater: State of the Knowledge on Sources, Fate and Solutions". *Marine Pollution Bulletin* 129, no. 1 (2018/04/01/ 2018): 262-65

Prata, da Costa, Lopes, Duarte, and Rocha-Santos. "Effects of Microplastics on Microalgae Populations: A Critical Review". *Science of the Total Environment* 665 (May 15 2019): 400-05

Preston Davies, "Cost-Benefit Analysis of a Container Deposit Scheme: Report for the Auckland Council ", 2017, http://www.srgexpert.com/wp-content/uploads/2018/03/Container-Deposit-CBA-Report-Final.pdf.

Radio New Zealand. "Government Pledges Mandatory Phase-out of Plastic Bags", 12 August 2018

Raworth. *Doughnut Economics: Seven Ways to Think Like a 21st Century Economist.* Chelsea Green Publishing, 2017.

Reid, "Indigenous Sustainability Indicators for Māori Farming and Fishing Enterprises. A Theoretical Framework.", 2013.

Richardson, Gunn, Wilcox, and Hardesty. "Understanding Causes of Gear Loss Provides a Sound Basis for Fisheries Management". *Marine Policy* 96 (2018/10/01/ 2018): 278-84

Rios, Moore, and Jones. "Persistent Organic Pollutants Carried by Synthetic Polymers in the Ocean Environment". *Marine Pollution Bulletin* 54, no. 8 (Aug 2007): 1230-37

Rochman, Hoh, Kurobe, and Teh. "Ingested Plastic Transfers Hazardous Chemicals to Fish and Induces Hepatic Stress". *Scientific Reports* 3 (Nov 21 2013)

Rochman, Kurobe, Flores, and Teh. "Early Warning Signs of Endocrine Disruption in Adult Fish from the Ingestion of Polyethylene with and without Sorbed Chemical Pollutants from the Marine Environment". *Science of the Total Environment* 493 (Sep 15 2014): 656-61

Rochman, Tahir, Williams, Baxa, Lam, Miller, Teh, Werorilangi, and Teh. "Anthropogenic Debris in Seafood: Plastic Debris and Fibers from Textiles in Fish and Bivalves Sold for Human Consumption". *Scientific Reports* 5 (Sep 24 2015)

Rockstrom, Steffen, Noone, Persson, Chapin, Lambin, Lenton*, et al.* "Planetary Boundaries: Exploring the Safe Operating Space for Humanity". *Ecology and Society* 14, no. 2 (2009)

Rotjan, Sharp, Gauthier, Yelton, Lopez, Carilli, Kagan, and Urban-Rich. "Patterns, Dynamics and Consequences of Microplastic Ingestion by the Temperate Coral, <I>Astrangia Poculata</I>". *Proceedings of the Royal Society B: Biological Sciences* 286, no. 1905 (2019): 20190726

Royal, "Mātauranga Māori: Paradigms and Politics. A Paper Presented to the Ministry for Research, Science and Technology. ." 1998.

Royal Society Te Apārangi, "Plastics in the Environment: Te Ao Hurihuri – the Changing World." 2019.

Royer, Ferron, Wilson, and Karl. "Production of Methane and Ethylene from Plastic in the Environment". *Plos One* 13, no. 8 (Aug 1 2018)

Ryberg, Hauschild, Wang, Averous-Monnery, and Laurent. "Global Environmental Losses of Plastics across Their Value Chains". *Resources, Conservation and Recycling* 151 (2019/12/01/ 2019): 104459

Santana, Ascer, Custodio, Moreira, and Turra. "Microplastic Contamination in Natural Mussel Beds from a Brazilian Urbanized Coastal Region: Rapid Evaluation through Bioassessment". *Marine Pollution Bulletin* 106, no. 1-2 (May 2016): 183-89

SAP news. "Sap Launches 'Plastics Cloud' to Help Reduce Single-Use Plastic Waste", press release, 17 September 2018, https://news.sap.com/uk/2018/09/sap-launches-plastics-cloud-to-help-reduce-single-use-plastic-waste/

Satherley. "The Kiwi Town Making Roads out of Plastic", *Newshub*, 7 June 2019

Schmidt, Krauth, and Wagner. "Export of Plastic Debris by Rivers into the Sea". *Environmental Science & Technology* 51, no. 21 (Nov 7 2017): 12246-53

Scion. "Annual Report". (2017)

Scion. "Nz Made, Wood Fill 3d Printing Filament Hits the 'Shelves'." *Scion Connections*, June 2018 2018

Scion. "Plastics Nz Awards and Launch of Plastics Roadmap", press release, 20 May 2019, https://www.scionresearch.com/about-us/news-and-events/news/2019/plastics-nz-awards-and-launch-of-plastics-roadmap

Scott Metcalfe. "A Kick in the Butt: Time to Address Tobacco Waste in New Zealand". 130, no. 1456 (2017)

Setala, Fleming-Lehtinen, and Lehtiniemi. "Ingestion and Transfer of Microplastics in the Planktonic Food Web". *Environmental Pollution* 185 (Feb 2014): 77-83

Shields. "Are Plastic-Eating Enzymes Our Planet's Only Hope?", *howstuffworks.com*, 17 September 2019

Smith. "Do Microplastic Residuals in Municipal Compost Bioaccumulate in Plant Tissue?", Royal Roads University, 2018

Song, Yeo, Kohls, and Herrmann. "Industrial Symbiosis: Exploring Big-Data Approach for Waste Stream Discovery". *24th Cirp Conference on Life Cycle Engineering* 61 (2017): 353-58

Statistics New Zealand. "In the Bag – Kiwis React to Banning Single-Use Plastic Bags", press release, 29 July 2019, http://www.scoop.co.nz/stories/BU1907/S00705/in-the-bag-kiwis-react-to-banning-single-use-plastic-bags.htm

Staub. "Recycled Plastic Mandate Advances in California", *Plastics Recycling Update*, 24 April 2019

Stoof, and Pickering. "Sustainable Composite Fused Deposition Modelling Filament Using Recycled Pre-Consumer Polypropylene". *Composites Part B: Engineering* 135 (2018/02/15/ 2018): 110-18

Stuff. "All Blacks' New Training Kit to Be Made from Recycled Plastic", 1 April 2019

Sussarellu, Suquet, Thomas, Lambert, Fabioux, Pernet, Le Goic*, et al.* "Oyster Reproduction Is Affected by Exposure to Polystyrene Microplastics". *Proceedings of the National Academy of Sciences of the United States of America* 113, no. 9 (Mar 1 2016): 2430-35

Sutton, "Understanding Microplastic Levels, Pathways, and Transport in the San Francisco Bay Region." 2019, https://www.sfei.org/documents/understanding-microplastics.

Szaky. *The Future of Packaging: From Linear to Circular.* United States: Berrett-Koehler Publishers, 2019.

Taylor. "Can Norway Help Us Solve the Plastic Crisis, One Bottle at a Time?", *The Guardian*, 12 July 2018

Taylor. "A Rubbish Idea: How Blockchains Could Tackle the World's Waste Problem", *The Conversation*, 9 April 2018

Teuten, Saquing, Knappe, Barlaz, Jonsson, Bjorn, Rowland*, et al.* "Transport and Release of Chemicals from Plastics to the Environment and to Wildlife". *Philosophical Transactions of the Royal Society B-Biological Sciences* 364, no. 1526 (Jul 27 2009): 2027-45

The Packaging Forum. "Public Place Recycling: Voluntary Product Stewardship Scheme ". (2016)

The Recycling Partnership, "The Bridge to Circularity: Putting the New Plastics Economy into Practice in the U.S.", 2019.

Tonkin & Taylor, "New Zealand Non-Municipal Landfill Database." 2014.

Torkashvand, and Farzadkia. "A Systematic Review on Cigarette Butt Management as a Hazardous Waste and Prevalent Litter: Control and Recycling". *Environmental Science and Pollution Research* 26, no. 12 (April 01 2019): 11618-30

Toussaint, Raffael, Angers-Loustau, Gilliland, Kestens, Petrillo, Rio-Echevarria, and Van den Eede. "Review of Micro- and Nanoplastic Contamination in the Food Chain". *Food Additives & Contaminants: Part A* 36, no. 5 (2019/05/04 2019): 639-73

Toussaint, Raffael, Angers-Loustau, Gilliland, Kestens, Petrillo, Rio-Echevarria, and Van den Eede. "Review of Micro- and Nanoplastic Contamination in the Food Chain". *Food Additives and Contaminants Part a-Chemistry Analysis Control Exposure & Risk Assessment* 36, no. 5 (2019): 639-73

Trager. "Concerns Raised over 'Regrettable' Bpa Substitutions", *Chemistry World*, 22 August 2019

Turner, Wallerstein, Arnold, and Webb. "Marine Pollution from Pyroplastics". *Sci Total Environ* 694 (Jul 29 2019): 133610

UK Government Office for Science, "Future of the Sea: Plastic Pollution." 2017, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/634433/Future_of_the_sea_-_plastic_pollution_final.pdf.

UN General Assembly, "Transforming Our World: The 2030 Agenda for Sustainable Development September 25, 2015." 2016, https://www.refworld.org/docid/57b6e3e44.html.

UNEP, "Global Chemicals Outlook Ii: From Legacies to Innovative Solutions: Implementing the 2030 Agenda for Sustainable Development – Synthesis Report." 2019, https://wedocs.unep.org/bitstream/handle/20.500.11822/27651/GCOII_synth.pdf?sequence=1&isAllowed=y.

UNEP, "Global Chemicals Outlook Ii: Summary for Policymakers." 2019.

UNEP, "Marine Litter Vital Graphics." 2016, https://wedocs.unep.org/bitstream/handle/20.500.11822/9798/-Marine_litter_Vital_graphics-2016MarineLitterVG.pdf.pdf?sequence=3&isAllowed=y.

UNEP, "Plastics and Shallow Water Coral Reefs: Synthesis of the Science for Policy-Makers." 2019.

UNEP, "Single-Use Plastics: A Roadmap for Sustainability." 2018, https://wedocs.unep.org/bitstream/handle/20.500.11822/25496/singleUsePlastic_sustainability.pdf?sequence=1&isAllowed=y.

Unilever. "Unilever Pioneers Solution That Enables Black Plastic Bottles to Be Recycled", press release, 16 May 2019, https://www.unilever.co.uk/news/press-releases/2019/unilever-pioneers-solution-that-enables-black-plastic-bottles-to-be-recycled.html

Van Cauwenberghe, and Janssen. "Microplastics in Bivalves Cultured for Human Consumption". *Environmental Pollution* 193 (10// 2014): 65-70

van Sebille, Wilcox, Lebreton, Maximenko, Hardesty, van Franeker, Eriksen*, et al.* "A Global Inventory of Small Floating Plastic Debris". *Environmental Research Letters* 10, no. 12 (Dec 2015)

Verdon. "Lego's Latest Green Initiative Wants to Put Old Bricks to New Use." *Forbes*, 8 October 2019 2019

W Snow, "Costs and Benefits of a Container Deposit Scheme for New Zealand: Review of the Packaging Forum's 2016 Cba of a Cds for New Zealand." 2016, https://www.nzpsc.nz/wp-content/uploads/2017/12/Review-of-PF-CDS-Report-July-2016.pdf.

Wagner, and Reemtsma. "Things We Know and Don't Know About Nanoplastic in the Environment". *Nature Nanotechnology* 14, no. 4 (2019/04/01 2019): 300-01

Ward, Armstrong, Walsh, Jackson, and Reddy. "Sunlight Converts Polystyrene to Carbon Dioxide and Dissolved Organic Carbon". *Environmental Science & Technology Letters* (2019/10/10 2019)

Ward, and Kach. "Marine Aggregates Facilitate Ingestion of Nanoparticles by Suspension-Feeding Bivalves". *Marine Environmental Research* 68, no. 3 (Sep 2009): 137-42

Ward, and Shumway. "Separating the Grain from the Chaff: Particle Selection in Suspension- and Deposit-Feeding Bivalves". *Journal of Experimental Marine Biology and Ecology* 300, no. 1-2 (Mar 31 2004): 83-130

Waste & Resources Action Programme (WRAP), "Framework for Greater Consistency in Household Recycling for England." 2016, http://static.wrap.org.uk/consistancy/Read_more_about_the_framework.pdf.

Waste & Resources Action Programme (WRAP), "A Methodology for Quantifying the Environmental and Economic Impacts of Reuse." 2011, http://www.wrap.org.uk/sites/files/wrap/Final%20Reuse%20Method.pdf.

Waste Not Consulting, "National Litter Survey 2014-2015: Summary of Results." 2015, https://www.recycling.kiwi.nz/files/3914/3201/1821/National_Litter_Survey_1415_e.pdf.

Waste Not Consulting, "National Litter Survey 2017-2019: Summary of Results." 2018, https://www.recycling.kiwi.nz/files/5315/3023/4734/2nd_National_Litter_Survey_June_2018_publication.pdf.

Waste Not Consulting, "National Recovery Rate for Beverage Containers." 2018.

WasteMINZ, "Product Stewardship: What Our Members Think." 2018, http://www.wasteminz.org.nz/wp-content/uploads/2018/07/WasteMINZ-Members-Product-Stewardship-Research.pdf.

WasteMINZ, "Technical Guidelines for Disposal to Land." 2018, http://www.wasteminz.org.nz/wp-content/uploads/2016/04/Technical-Guidelines-for-Disposal-to-Land-9Aug18-FINAL.pdf.

WasteMINZ Organic Materials Sector Group, "Guides to Terminology for Compostable; Biodegradable, and Oxo-Degradable Products", https://www.wasteminz.org.nz/pubs/guides-to-compostable-packaging-terminology/

WasteMINZ Territorial Authority Forum, "Local Government Waste Manifesto." 2018, https://www.wasteminz.org.nz/wp-content/uploads/2018/01/Local-Government-Waste-Manifesto-final-22012018.pdf.

Webb, Ruffell, Marsden, Pantos, and Gaw. "Microplastics in the New Zealand Green Lipped Mussel Perna Canaliculus". *Marine Pollution Bulletin* 149 (2019/12/01/ 2019): 110641

Wilcox, Van Sebille, and Hardesty. "Threat of Plastic Pollution to Seabirds Is Global, Pervasive, and Increasing". *Proceedings of the National Academy of Sciences of the United States of America* 112, no. 38 (Sep 22 2015): 11899-904

Willis, Maureaud, Wilcox, and Hardesty. "How Successful Are Waste Abatement Campaigns and Government Policies at Reducing Plastic Waste into the Marine Environment?". *Marine Policy* 96 (Oct 2018): 243-49

World Economic Forum, "The New Plastics Economy: Rethinking the Future of Plastics." 2016, http://www3.weforum.org/docs/WEF_The_New_Plastics_Economy.pdf.

World Health Organization, "Microplastics in Drinking-Water." 2019, https://www.who.int/water_sanitation_health/publications/microplastics-in-drinking-water/en/.

World Wildlife Fund, "Living Blue Planet Report: Species, Habitats and Human Well-Being." 2015, https://c402277.ssl.cf1.rackcdn.com/publications/817/files/original/Living_Blue_Planet_Report_2015_Final_LR.pdf?1442242821.

Wright, Rowe, Thompson, and Galloway. "Microplastic Ingestion Decreases Energy Reserves in Marine Worms". *Current Biology* 23, no. 23 (Dec 2013): R1031-R33

Xing, Xu, Shi, and Lian. "The Impact of Pm2.5 on the Human Respiratory System". *Journal of Thoracic Disease* 8, no. 1 (2016): E69-E74

Yeo, Takada, Taylor, Ito, Hosoda, Allinson, Connell, Greaves, and McGrath. "Pops Monitoring in Australia and New Zealand Using Plastic Resin Pellets, and International Pellet Watch as a Tool for Education and Raising Public Awareness on Plastic Debris and Pops". *Marine Pollution Bulletin* 101, no. 1 (2015/12/15/ 2015): 137-45

Yokota, Waterfield, Hastings, Davidson, Kwietniewski, and Wells. "Finding the Missing Piece of the Aquatic Plastic Pollution Puzzle: Interaction between Primary Producers and Microplastics". *Limnology and Oceanography Letters* 2, no. 4 (Aug 2017): 91-104

Yoshida, Hiraga, Takehana, Taniguchi, Yamaji, Maeda, Toyohara*, et al.* "A Bacterium That Degrades and Assimilates Poly (Ethylene Terephthalate)". *Science* 351, no. 6278 (2016): 1196-99

Young, and Adams. "Plastic Debris and Seabird Presence in the Hauraki Gulf, New Zealand". *New Zealand Journal of Marine and Freshwater Research* 44, no. 3 (2010/09/01 2010): 167-75

Zero Waste Europe, "El Dorado of Chemical Recycling: State of Play and Policy Challenges." 2019, https://zerowasteeurope.eu/wp-content/uploads/edd/2019/08/2019_08_29_zwe_study_chemical_recycling.pdf.

Zheng, and Suh. "Strategies to Reduce the Global Carbon Footprint of Plastics". *Nature Climate Change* 9, no. 5 (2019/05/01 2019): 374-78

Zheng, and Suh. "Strategies to Reduce the Global Carbon Footprint of Plastics". *Nature Climate Change* (05/01 2019)

Zumstein, Schintlmeister, Nelson, Baumgartner, Woebken, Wagner, Kohler, McNeill, and Sander. "Biodegradation of Synthetic Polymers in Soils: Tracking Carbon into Co2 and Microbial Biomass". *Science Advances* 4, no. 7 (Jul 2018)

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Office of the Prime Minister's Chief Science Advisor

The University of Auckland

Private Bag 92019

Victoria Street West

Auckland 1142

Aotearoa New Zealand

Phone 64 9 923 6318

Email info@pmcsa.ac.nz

Website pmcsa.ac.nz

Instagram @nz_chief_science_advisor

Twitter @ChiefSciAdvisor

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