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

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REPORT: Rethinking Plastics in Aotearoa New Zealand - Key Messages

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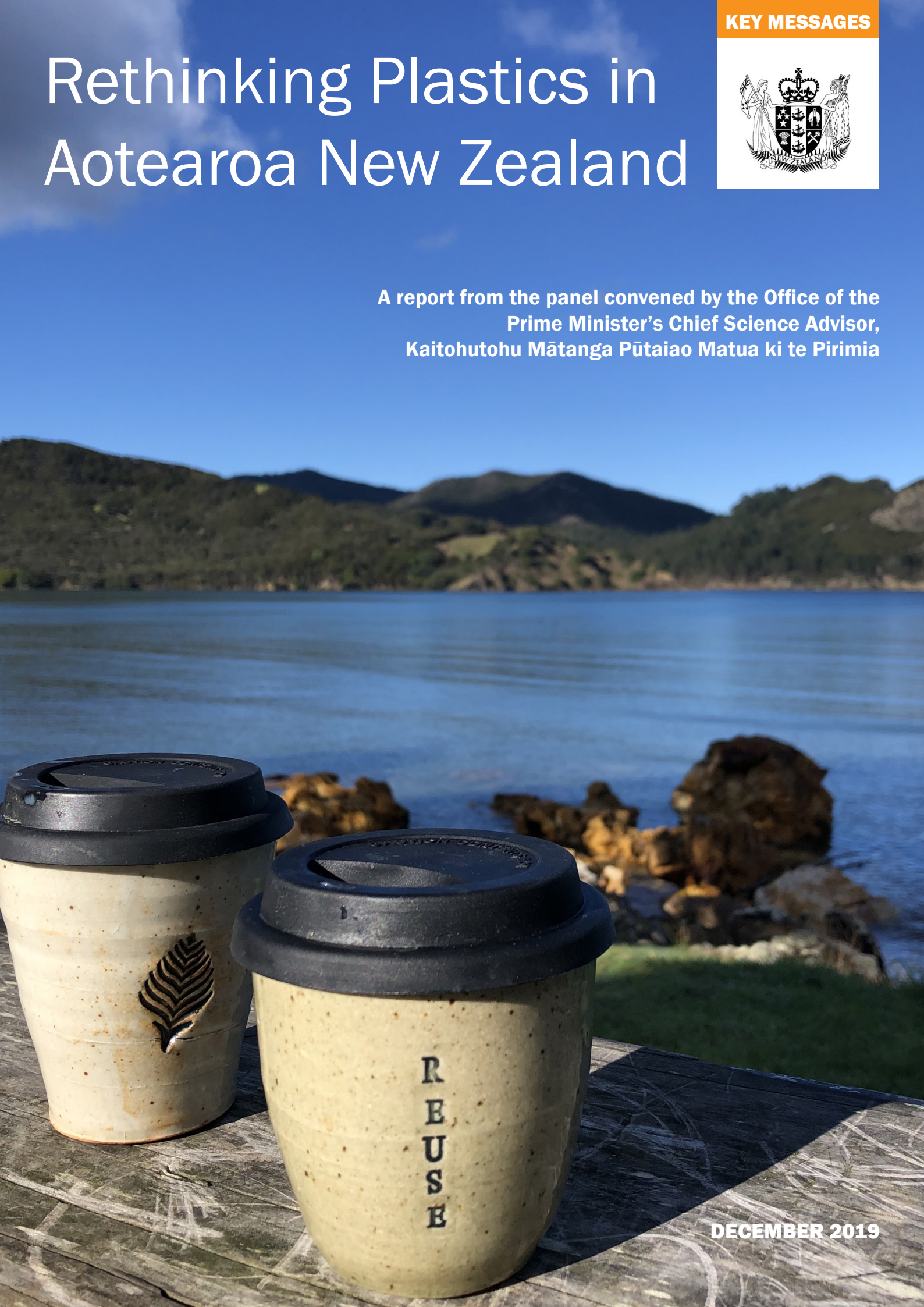
KEY MESSAGES

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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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 short report captures the key messages from our work. The full report, available from our website, is long, detailed and multifaceted, presenting the evidence-base, the gaps in information, and ideas to inspire change. 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

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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 5

[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.

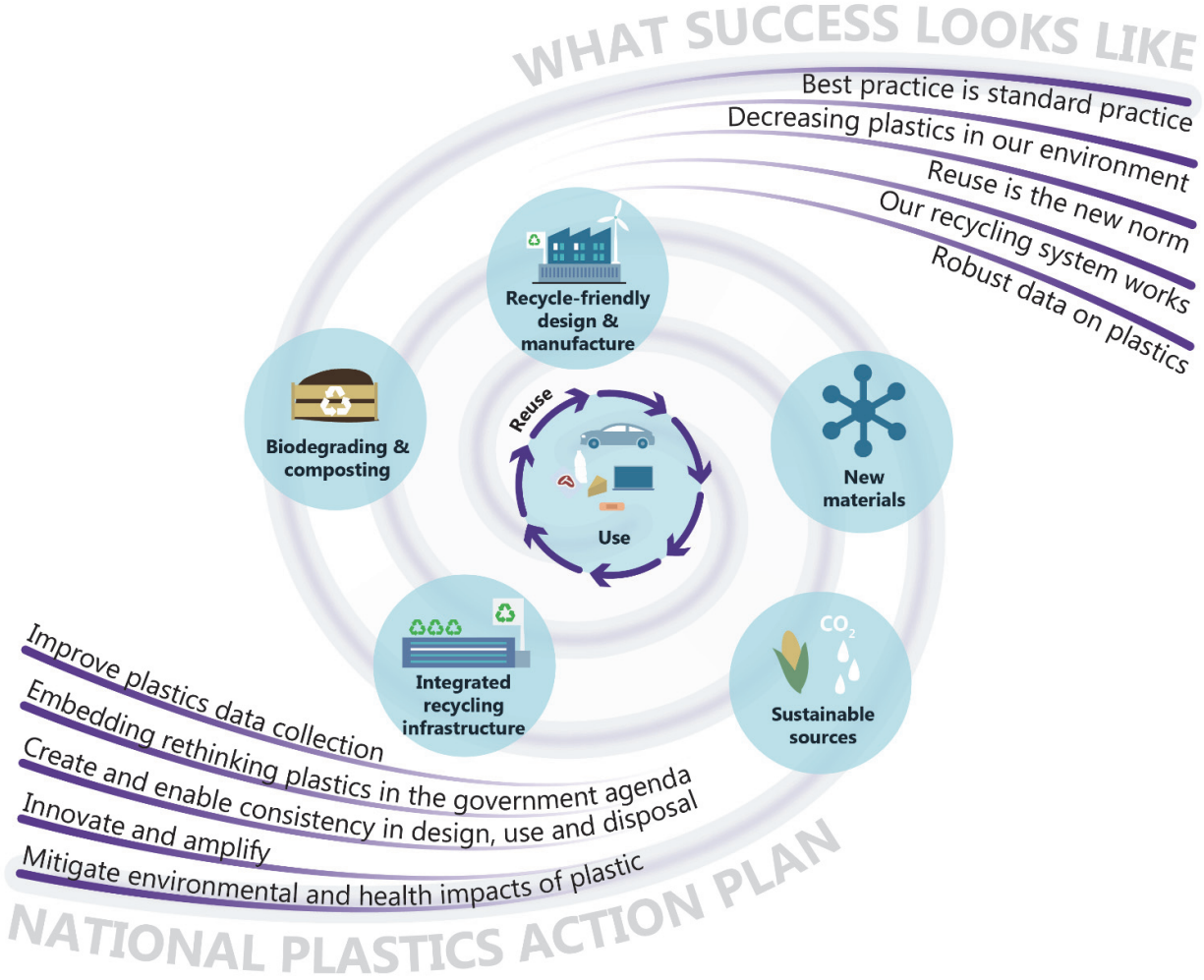

Figure 1 The Rethinking Plastics panel's vision for Aotearoa New Zealand

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Our panel

We gratefully acknowledge the efforts and good humour of our hard-working panel.

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- Professor Sarah McLaren, Massey University
- 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)*

Organisation of the Rethinking Plastics Project Report

Workstreams

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:

1) **Motivation for rethinking plastics:** 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.
2) **Changing our relationship with plastics:** 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.
3) **Ideas for a more sustainable future – embracing innovation:** 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.
4) **Plastics and the environment – life cycle assessment and beyond:** 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 through its whole life cycle – not just 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.
5) **To what extent can we quantify Aotearoa's plastic? New Zealand's data challenge:** 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.

In the full report, each chapter brings together an evidence-base and expert opinion for one of these workstreams, along with case studies and specific solutions or recommendations. This short report distils out the key messages from each chapter.

Outputs

Several outputs have come from the Rethinking Plastics project:

- **This short report,** summarising the key messages that emerged from our detailed thinking.
- **The full report,** which is long and detailed, expanding on the ideas in this short report, available as a complete document or a series of five themed chapters on our website.
- **A website** where the detailed findings are available in an accessible format for different audiences.
- **A resource portal** on our website that links to key sources of information (https://www.pmcsa.ac.nz/our-projects/plastics/rethinkplastics-resources/), because 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.

THIS IS THE SHORT VERSION OF AN EXTENSIVE FULL REPORT.

All documents, images and case studies related to Rethinking Plastics are available at https://www.pmcsa.ac.nz/our-projects/plastics/

1. Motivation for rethinking plastics: key messages

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, 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 the generations to come.

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

Figure 3 Plastic waste picked up on a beach in Aotearoa New Zealand

With increased knowledge and media 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, including plastic shopping bags in Aotearoa New Zealand, which aims to decrease the overall amount of plastic use and pollution.[3] 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 sustainably and responsibly. Establishing onshore reprocessing capabilities and a national recycling framework that is simple to use for individuals, communities and businesses are critical early steps. Rethinking plastics will be an ongoing process that requires continuous innovation and improvement with the expectation that best practice becomes standard practice.

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 to take us further down the track.

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

[3] UNEP, "Single-Use Plastics: A Roadmap for Sustainability", 2018

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. Over 100,000 New Zealanders have signed petitions to the government to ban single-use plastic bags in recent years.[4] 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.[5] 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.[6]

Aotearoa New Zealand has commitments to the global community

We are already engaged in several 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. We also have a responsibility to support nations in the South Pacific to manage plastics better. Pacific leaders describe plastic 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. These commitments need organising, prioritising and turning into actions at home and across borders.

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. Some of the deeper dives into the issue, including excellent recent reports from the Parliamentary Commissioner for the Environment and the Royal Society Te Apārangi are available through our plastics resource page (https://www.pmcsa.ac.nz/our-projects/plastics/rethinkplastics-resources/). With the growing need for action, it is important that different workstreams are shared where appropriate. This will help harness shared ambition and coordinate the transition to a more circular economy for plastics.

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 recycled content. This leads to confusion. For example, not all biobased plastics are bidegradable and not all biodegradable plastics are biobased.

Classification based on	Examples
Physical properties	'Thermoplastic' or 'thermoset'
Resin type (chemical make-up)	'PET (#1)' or 'HDPE (#2)'
Feedstock (what is made from)	Bio-based
Chemical additives in the material	Oxo-degradable
How it will break down	Biodegradable, compostable or non-biodegradable

[4] Ministry for the Environment, "Proposed Mandatory Phase out of Single-Use Plastic Shopping Bags: Consulation Document", 2018
[5] Colmar Brunton, "Better Futures 2019", 2019
[6] Brooks et al., "The Chinese Import Ban and Its Impact on Global Plastic Waste Trade," *Science Advances* 4, no. 6 (2018)

Guiding frameworks

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. The dynamic and inter-connected perspective of te ao Māori 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. Rethinking plastics presents an opportunity to embrace kaitiakitanga in a contemporary setting, as a guiding principle. The concept of stewardship aligns well with circular economy solutions and inspires innovation.

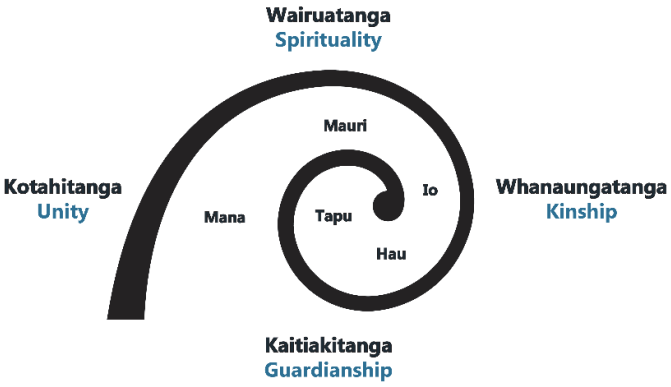

Figure 4 The koru of Māori ethics developed by Manuka Henare

Circular economy

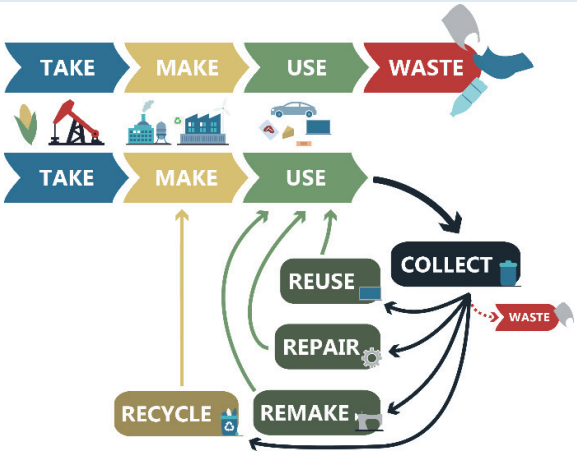

Figure 5 Reuse, repair, remaking and recycling can support the transition from a linear to circular economy for plastics

Aotearoa New Zealand has started to embrace elements of a circular economy by establishing the New Zealand Plastic Packaging Declaration of June 2018 and signing the New Plastics Economy Global Commitment led by the Ellen MacArthur Foundation (EMF) in collaboration with the UN Environment Programme, agreeing to meet stringent targets, including the commitment to ensure that 100% of plastic packaging can be easily and safely reused, recycled, or composted by 2025. A circular economy is aspirational and may not be realised for some time. However, it does stimulate thinking and we might usefully plan in the medium term 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.

Waste hierarchy and the 6Rs

The waste hierarchy and 6Rs (which vary with different sources, but here are referred to as rethink, refuse, replace, reduce, reuse and recycle) are helpful frameworks to guide rethinking plastics. Much of the current discussion around how to remedy Aotearoa New Zealand's model of plastic use focuses on improving the recycling system. However, the most impactful step would be to use less plastic in the first place when feasible. This challenges us to innovate, create new materials and new ways of using them, and develop new business models.

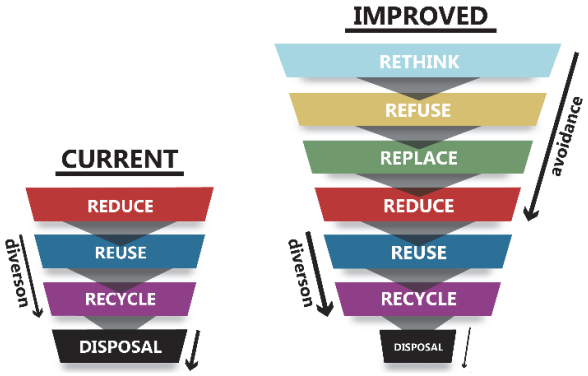

Figure 6 The current waste hierarchy can be updated to prioritise avoiding the use of the material if feasible

2. Changing our relationship with plastics: key messages

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. 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 ways that are innovative, benefit society and protect the environment. Evolving our relationship with plastics requires transformative action across the whole system of plastic use (see Figure 7). 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. 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. We recommend a national plastics action plan.

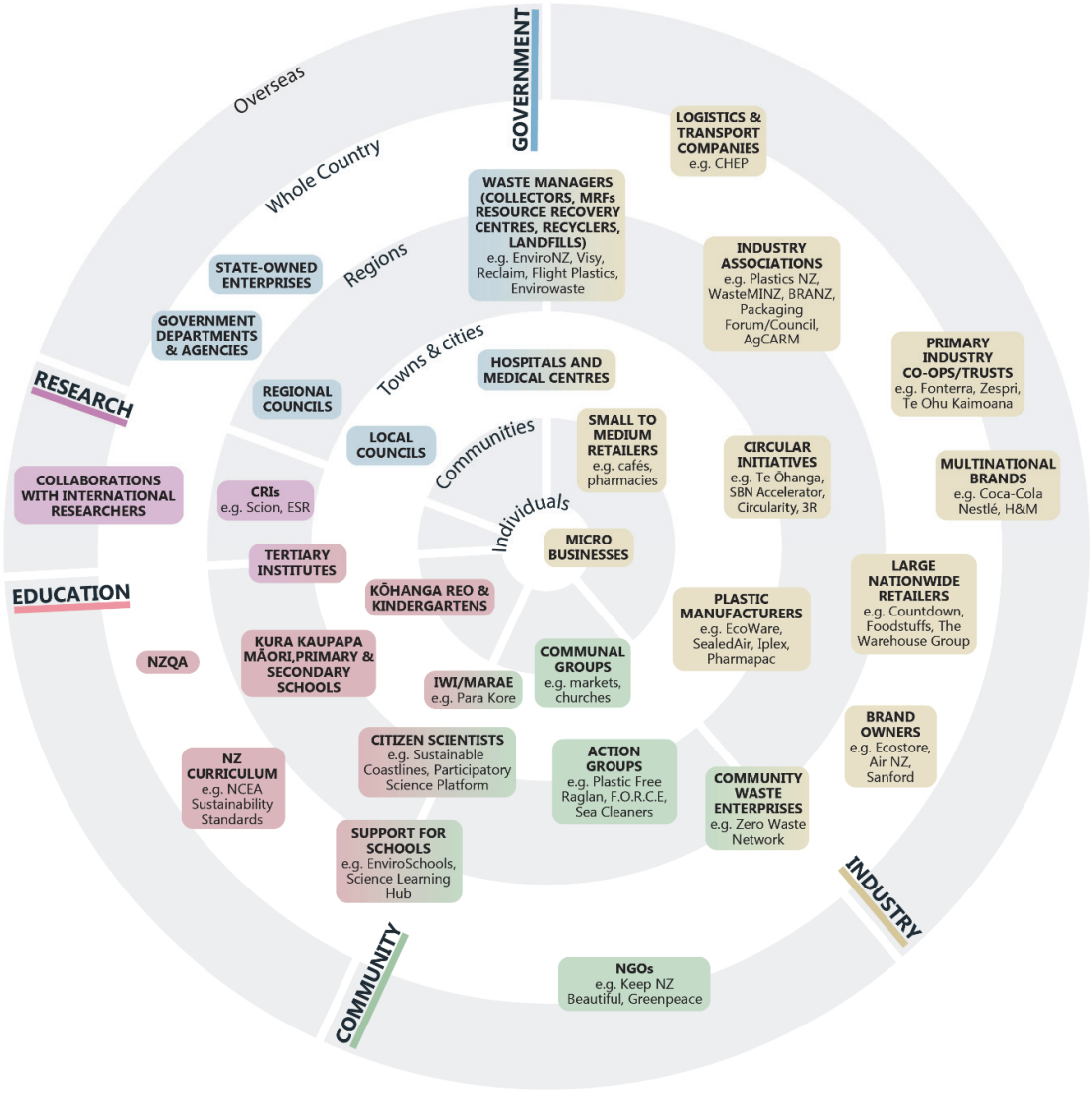

Figure 7 Plastics in Aotearoa New Zealand: an illustration of the wide variety of groups whose actions can contribute to transformational change

Central Government action

The New Zealand Government can provide leadership that will enable our country to create lasting changes to our relationship with plastics, through setting a vision with a national plastics action plan and establishing a regulatory framework to support it. Establishing these will accelerate change, support good practice and create fair, uniform rules within industry. Because regulation can be slow to implement, signalling these best practice expectations can be the initial basis upon which businesses start to make changes. Central government can also support community-led initiatives and the public to challenge their relationship with plastics by removing barriers to action, demonstrating best practice, and driving public education around issues related to plastics. Embedding sustainable plastic use in the Government's agenda through national frameworks and processes and trade policy will help to ensure the efforts to rethink plastics are enduring.

THE NEW ZEALAND GOVERNMENT CAN PROVIDE LEADERSHIP THAT WILL ENABLE OUR COUNTRY TO CREATE LASTING CHANGES TO OUR RELATIONSHIP WITH PLASTICS, THROUGH SETTING A VISION WITH A NATIONAL PLASTICS ACTION PLAN AND ESTABLISHING A REGULATORY FRAMEWORK TO SUPPORT IT

Local Government action

Through their role in providing waste management and recycling services, public education, and connecting with and supporting community and school initiatives, local governments have a responsibility to help drive cultural transformation in how we use and dispose of plastic. Local councils can support rethinking plastics through a variety of actions that relate to:

- Communicating and educating the public and local businesses: e.g. providing detailed information about recycling and waste to local residents
- Fostering new ideas in the community: e.g. supporting initiatives that help develop skills and ideas within the community and local businesses to reduce plastic use
- Direct action: e.g. collaborating with other councils for consistency in systems and data collection, and economies of scale.

Councils bear the brunt of a lot of the issues related to the fragile recycling system and the resourcing required and cost burden of managing plastic waste. This is made worse by limited flexibility in contracts and existing infrastructure, limited data, and the current lack of an incentive to embed sustainable plastic use into procurement guidelines. One of the biggest barriers to action from local and regional councils is the lack of a clear national vision and action plan to which councils can align their management of plastics. 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.

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, develop evidence-based solutions, put systems in place that facilitate good practice, and get widespread support within the industry to change the practice.

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. 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. The local plastics manufacturing industry need support from government to shift to more sustainable use of plastics and a regulatory framework to reduce environmental impacts currently associated with the industry.

Examples of actions that could be adopted by an industry include:

- Making declarations and setting targets
- Developing product stewardship schemes
- Collaborating on industry-wide workplace education
- Developing accreditation and certification schemes
- Standardising data collection.

SECTOR-LED ACTION ON RETHINKING PLASTICS HAS THE POTENTIAL TO DRIVE A COLLECTIVE SOLUTION AT SCALE AND WITH PACE

Business-led action

All companies, from micro-businesses to small-to-medium enterprises (SMEs) through to multinationals, have a significant role in changing the way plastic is utilised in production, distribution and consumer use, but the competitive nature of the business sector makes it difficult to ensure widespread uptake of responsible plastic use without backing from legislation. Most businesses, particularly SMEs, 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.

Businesses can lead a 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. This can be achieved through:

- Market-facing initiatives: e.g. making declarations and setting targets about reducing non-renewable plastic production and waste
- Operational actions: e.g. redesigning products or packaging to improve recyclability in Aotearoa New Zealand
- Supply chain actions: e.g. auditing the supply chain to look for opportunities to reduce plastic use.

Community-led action

Community groups and initiatives, not-for-profit and non-governmental organisations play 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. 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.

Community action on plastics can be strengthened through:

- Engaging with local schools and marae, or connecting with national initiatives to establish a local arm
- Using clean-up efforts as an opportunity to collect data (and standardise this nationwide)
- Sharing successful community initiatives to inspire other community groups.

The reliance on volunteers and limited funding can make it difficult for community initiatives to take hold. Further support from central and local government, and connection with other groups, can help to address these barriers.

Initiating changes through education

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. 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. Educational programmes can be strengthened by connection with the local council, marae, community groups or citizen science projects related to plastics.

Tertiary education also provides opportunities for learning and action and supports a wider shift in society through leadership and research. In particular, these groups 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.

The cumulative power of individual actions

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. 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 through reuse or recycling.

Part of a global community

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. 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.

There are numerous opportunities to take action as part of a global solution, including:

- Embedding more sustainable use and management of plastics in trade agreements and establishing international product stewardship principles
- Aligning efforts with those that are leading the charge through agreements and initiatives
- Fostering international research collaborations, including connecting to research by indigenous communities in other countries
- Connecting local citizen science efforts to international citizen science projects.

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

3. Ideas for a more sustainable future – embracing innovation: key messages

Plastics are 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.

Figure 8 The 6Rs guide our ideas and innovations for rethinking plastics

THERE IS NO SILVER BULLET

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. 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.

There are many 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 used to ensure that we are not creating further environmental or health risks with them. It is important to be wary of unintended consequences.

Rethink

Many of the issues raised by plastics are not caused by the properties of the plastics themselves but by the way we design and use them. Plastic 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 or health.

Rethinking and redesigning plastics requires a whole-of-life accounting approach to better account for the environmental and social costs of plastic and not just the cost of putting a product on the market. Product stewardship schemes are one way to begin this.[7] Ideas that could form part of a system-wide rethink in how we use plastic include:

- Guidelines and a code of practice for industry: e.g. UK guidelines (WRAP)
- Sustainable product design so all resources stay in the economy: as highlighted by the Ellen MacArthur Foundation
- New business models based on leasing vs ownership and the 'sharing' economy: e.g. Again Again coffee cups
- Circular system redesign through collaboration, use of AI and/or big data and blockchain: e.g. Coreo's circular experiment.

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 and reuse, and recycling options. Approaches that can reduce the overall amount of plastic entering the market include:

- Banning certain single-use plastic products and types of plastic for certain applications: e.g. EU and Canada banning certain single-use products and types of plastic, and Aotearoa New Zealand's single-use plastic bag ban
- Concentrated and compressed products which eliminate plastic packaging: e.g. Ethique's beauty bar products.

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.[8] 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. 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 bio-based plastics where possible. Brands can work to reduce the amount of plastic used in certain applications through:

- Light-weighting materials: e.g. Nestlé reducing the weight of their water bottles by 22%
- Changing the product to reduce required plastic packaging: e.g. Unilever made a laundry liquid 6x more concentrated and reduced plastic volume by 75%.

Reuse

There has been a significant amount of innovation for reuse systems in recent years. EMF published a detailed report on reusable packaging, highlighting 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.[9] Different systems are needed for non-packaging industries and business to business packaging or products. Examples of reuse approaches related to plastics include:

- Reusable systems to replace single-use products or packaging: e.g. Globelet's reusable cup system
- Logistics innovation in supply chains: e.g. CHEP's reuse system for secondary and tertiary packaging
- Refill stations and services: e.g. Ecostore's refill stations across stores and supermarkets
- Logistics innovation to keep products in circulation: e.g. Lego's free returns system
- Sterilisation of single-use products for reuse: e.g. Medsalv's sterilisation system for medical devices.

[7] More information available at: https://www.mfe.govt.nz/waste/we-all-have-role-play/businesses-taking-responsibility-for-their-products
[8] World Economic Forum, "The New Plastics Economy: Rethinking the Future of Plastics", 2016
[9] Ellen MacArthur Foundation, "Reuse - Rethinking Packaging", 2019

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 inefficiencies of the current recycling system need to be addressed using a value-chain approach, with improvements made at all stages of the process, so that we can get the most out of the plastic materials used. This will include improving product design, better labelling and public education, improving and expanding collection systems, more effective sorting methods, investing in onshore infrastructure for certain types of plastic, turning to chemical recycling where needed in the future, and increasing the incorporation of recycled content in new products to get market pull-through, as illustrated in Figure 9.

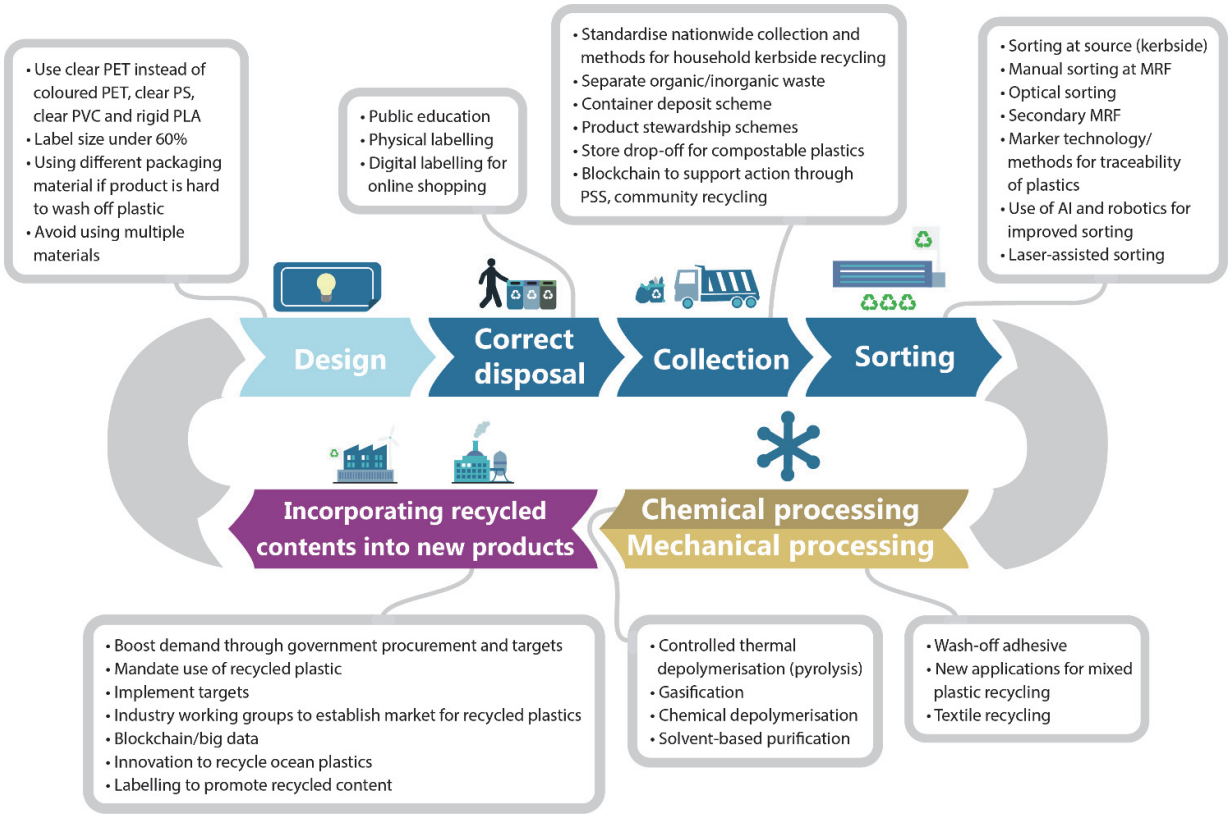

Figure 9 Examples of ways to improve recycling at various parts of the recycling value chain

Replace

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 applications. In the short-term, there are priority areas for innovation to replace particularly problematic materials. These include foils/laminates, synthetic fabrics that shed microfibres and difficult-to-recycle plastics used in packaging (PVC, PS and various resins that fall into the 'other' category).

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. Bioplastics currently comprise only 1% of total plastics production, so there is plenty of scope to increase the use of these plastics.
- Biodegradable and compostable plastics: 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.[10] Considerable research is being undertaken internationally and in Aotearoa New Zealand to solve current issues with compostable plastics.
- 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.

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

- Is it safe?
- Is this a better alternative for the environment?
- What might the unintended consequences be?
- How does it fit into the current and future system of circular materials?

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 US National Science Foundation Centre for Sustainable Polymers[11]). 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.

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. Aotearoa New Zealand currently relies on landfill to dispose of most waste plastic. 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:

- Cost: Upfront costs of developing a single waste-to-energy incineration plant being prohibitive
- Emissions: Transporting waste throughout the country to one plant would have a high emissions footprint
- Perverse outcomes: The plant itself requires a certain amount of waste to be economic – this could have the perverse outcome of incentivising waste production
- Scale required: Technology and infrastructure for smaller plants, which may be better suited to our local context, are not available at scale.

[10] Beyond the Bin, "A Review of the Availability of New Zealand Compost Facilities to Process Compostable Coffee Cupes and Food Packaging", 2017
[11] More information available at: http://csp.umn.edu/

4. Plastics and the environment – life cycle assessment and beyond: key messages

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.[12] There is a growing body of evidence that details the impacts of plastic that has leaked into the environment, which we summarise later.

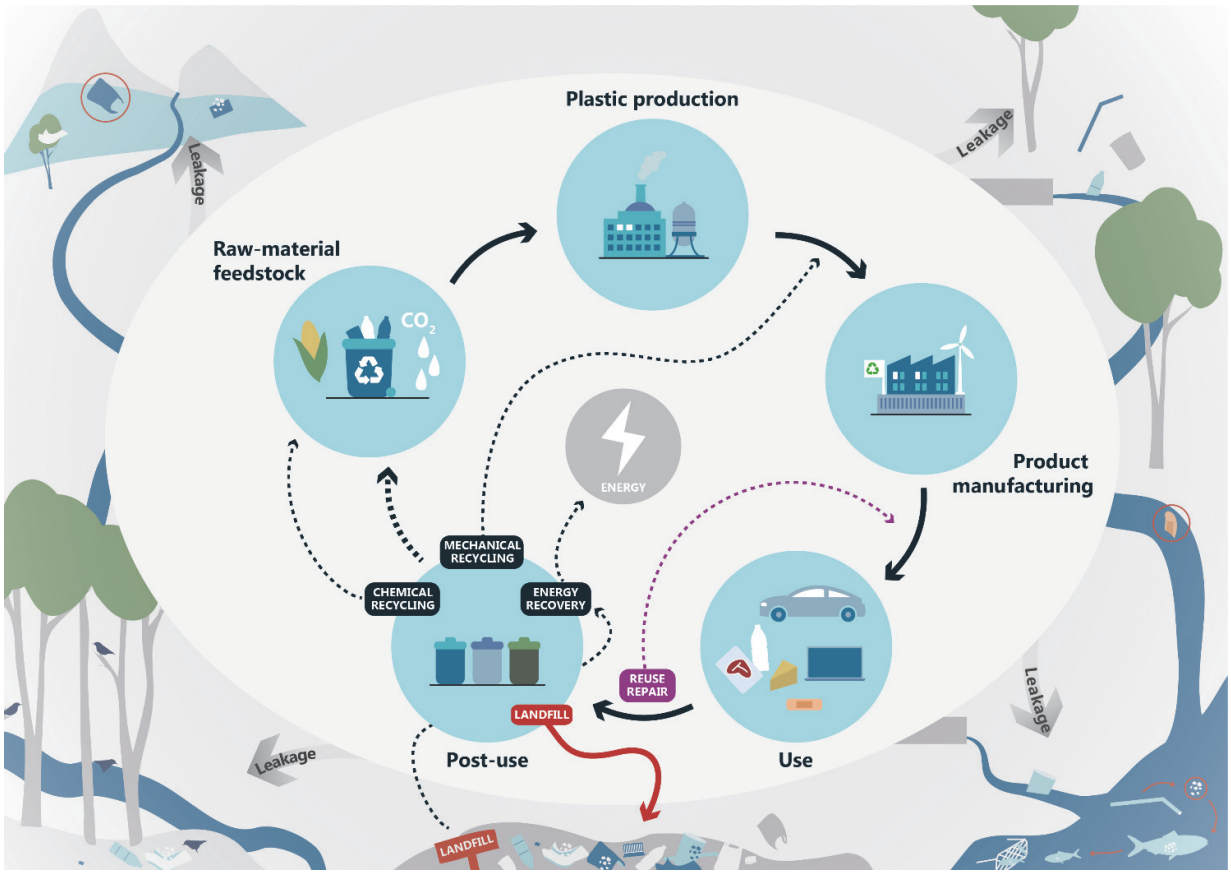

Figure 10 The life cycle of plastic from resource extraction of raw-material feedstock to end-of-life disposal and possible re-entry into the use cycle. Leakage into the environment is a potential end-of-life scenario. Adapted from Plastics Europe

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. Plastic products do not only have an impact on the environment at their 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. Other materials generate environmental impacts throughout the whole life cycle as well. The material that is the least environmentally

[12] More information available at: https://www.westlanddc.govt.nz/fox-landfill-clean

damaging will depend on context and application – evaluating differences in life-cycle environmental impacts in combination with the risks of environmental leakage for different materials can help guide these decisions.

Ensuring that the future production, consumption and disposal of plastics is sustainable and safe is consistent with wisdom from te ao Māori, 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. 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.

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. Emissions occur from:

- Extraction and transport
- Refining and manufacture
- Waste management
- Plastic in the environment.

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.[13]

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.[14] 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.[15] 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 aggressive application of renewable energy, recycling and demand-management strategies, and replacing fossil-fuel feedstock with biomass has the potential to reduce emissions from plastics and achieve an absolute reduction from the current level.[16]

The place for life cycle assessment in rethinking plastics

As well as thinking about the waste hierarchy, life cycle assessment (LCA) can be used to inform choices by evaluating and comparing the full life cycle environmental impact of different 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. The preferred product or system will also depend upon factors such as the geographical context, user behaviour, and structure of local waste management systems.

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, as illustrated in Table 1. The evidence for life-cycle environmental

[13] Plastics Europe, "The Impact of Plastics on Life Cycle Energy Consumption and Greenhouse Gas Emissions in Europe (Summary Report)," (2010)
[14] Center for International Environmental Law, "Plastic & Climate: The Hidden Costs of a Plastic Planet ", 2019
[15] World Economic Forum, "The New Plastics Economy: Rethinking the Future of Plastics", 2016
[16] Zheng et al., "Strategies to Reduce the Global Carbon Footprint of Plastics," *Nature Climate Change* 9, no. 5 (2019)

impacts of plastic should be used as part of the decision-making process, alongside social, health, technical and economic aspects of material choice. 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. 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.

Table 1 Examples of how life-cycle thinking can frame the issues related to plastics

Question	Example	Key messages
ARE REUSABLE PRODUCTS ALWAYS BETTER THAN SINGLE-USE ALTERNATIVES? Generally a reusable or durable product uses more material in its production and may have environmental impacts to keep it in use. 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	Most LCA studies comparing single-use plastic bags to alternatives such as a paper bag, a heavier reusable plastic bag or a cotton bag have not accounted for litter – but litter is one of the major concerns driving plastic bag bans An LCA study comparing bags that introduced a littering indicator found that the order of environmental favourability for environmental impacts was the opposite of the order determined by the littering indicator There are discrepancies between the best bag choices depending on whether you prioritise 'climate' vs 'litter'	The best environmental outcomes will come from extensive reuse of product and appropriate disposal at its end-of-life Durable products are likely to be environmentally preferable to single-use disposable alternatives, but only if they are reused many times to maximise their environmental benefits 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
SHOULD WE SWITCH TO 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 It is 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	Chen et al. used LCA to compare the environmental impacts from resource extraction to manufacture (cradle to factory gate) for types of PET plastic with varying proportions of bio-mass or fossil fuel feedstock There is not a clear answer – the type of material with the best and worst impacts changes depending on which impact is measured because converting a plant to a plastic sequesters carbon dioxide in a solid form; agricultural and forestry machinery is fossil-fuelled; power in the US (where the study is from) is mostly fossil-fuel-based, current processes to convert wood to PET precursors are energy and chemical intensive, and fertilisers and pesticides for crops require energy to make and have negative impacts on acidification, soil nutrients and ecotoxicity	At present, bio-based plastics are not necessarily environmentally better than fossil-fuel based plastics or other types of materials – it depends upon how they are produced and where they end up. Shifting to 100% bio-based plastics in conjunction with other changes may reduce the carbon footprint of plastics in the future For bio-based plastics, a systems-based analysis of potential feedstocks that factors in the full life cycle of the product, including whether it is biodegradable or can 'drop-in' to existing recycling processes, is necessary to ensure net environmental and other sustainability benefits

Question	Example	Key messages
IS RECYCLED PLASTIC ACTUALLY BETTER FOR THE ENVIRONMENT? The process of recycling plastic uses a number of resources, each with associated environmental impacts. Comparing these impacts against those associated with producing virgin resin can inform which the preferred material choice is	A theoretical situation of 100% recycling of plastic in 2050 found it had a 25% lower carbon footprint in 2050 relative to the current trajectory (business-as-usual) of plastic use up to 2050 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	Recycling plastic is likely to be environmentally beneficial, but there needs to be a demand to use the recycled 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 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 distance between material collection and recycling facilities will also have a significant bearing on the environmental impacts through energy used for transport
SHOULD WE BAN PLASTIC PACKAGING ALTOGETHER? We need to factor in the benefits of packaging that are lost if the packaging is removed. 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	In a 'cradle-to-gate' carbon footprint study of common breakfast foods eaten in California, 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. The exceptions were orange juice (13%), breakfast cereals (35%), and bread buns in single-serve packages (17%). The carbon footprint of paper packaging was lower than the plastic packaging, and glass packaging had the highest carbon footprint	A life cycle approach 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 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
SHOULD WE USE AN ALTERNATIVE MATERIAL TO PLASTIC? 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 – there might be environmental impact hotspots in the life cycle that are more important than the impacts of material production	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. However, care must be taken with these alternatives to ensure the quality and value of the wine is maintained	Whether plastic is the best material choice for a product depends on the context and the alternatives available Plastic is lighter than many other materials, and so may be preferred when the environmental hotspots of a product are associated with transportation If a product is at high risk of being littered, it's important to factor in the impacts of plastic leaking into the environment alongside the evidence from LCA

Question	Example	Key messages
SHOULD WE RESTRICT OUR USE OF PLASTIC TO CERTAIN TYPES? 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. 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	In NZ, 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 For other applications, changing to an alternative plastic 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	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 NZ context In the current NZ 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 the recycled material
WHAT END-OF-LIFE OPTIONS FOR PLASTIC ARE BEST FOR AOTEAROA NEW ZEALAND? LCA can be used an alternative approach to the widely cited waste hierarchy framework, which is based on end-of-life options rather than the whole-of-life environmental impacts, to determine the best end-of-life systems for plastic waste	In line with the waste hierarchy, LCA studies indicate that landfilling of waste is generally the worst end-of-life management option There are no publicly available LCAs assessing whether landfill or incineration with energy capture is a better environmental option for NZ. The results would be influenced by the transportation requirements between points of waste generation and incineration plants or landfills 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 Alternatively, there may be an increase in biodegradable or compostable plastics that enter landfill, and outcomes of the analysis may change, particularly if all is disposed to modern landfills with methane capture	The waste hierarchy is generally appropriate to guide end-of-life management of plastic products but this may not be the case for packaging where 'reduce' and 'reuse' may cause increased wastage of the packaged product, or where the plastic type cannot be separated out for recycling 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

Impacts of plastic leaked into our environment

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.[17]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.[18] 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.[19]

Figure 11 Goat Island, Leigh, Aotearoa New Zealand

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.[20] Studies estimating the volume of plastic debris on the ocean surface have discrepant findings due to different methods.[21] One study estimated between 7,000–35,000 tonnes on the sea surface,[22] while another estimated 93,000–236,000 tonnes.[23]

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

There are impacts on the environment throughout the whole life cycle of a plastic product, with particularly significant impacts if leaked into the environment (detailed in Table 2). 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.

[17] Jambeck et al., "Plastic Waste Inputs from Land into the Ocean," *Science* 347, no. 6223 (2015)
[18] Li et al., "Plastic Waste in the Marine Environment: A Review of Sources, Occurrence and Effects," *Science of the Total Environment* 566 (2016)
[19] Schmidt et al., "Export of Plastic Debris by Rivers into the Sea," *Environmental Science & Technology* 51, no. 21 (2017)
[20] UNEP, "Marine Litter Vital Graphics", 2016
[21] UK Government Office for Science, "Future of the Sea: Plastic Pollution", 2017
[22] 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)
[23] van Sebille et al., "A Global Inventory of Small Floating Plastic Debris," *Environmental Research Letters* 10, no. 12 (2015)

Table 2 The impacts of plastic on our environment and what it means for Aotearoa New Zealand

Impact	The biggest concerns	What it means for Aotearoa New Zealand
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	The effects are widespread It negatively affects biodiversity We don't know the extent of the impacts The problem will compound	NZ's local wildlife and taonga species are physically harmed by plastic pollution As home to one-third of all species of seabird and the breeding ground for the highest number of seabird species worldwide, plastic debris in our seas poses a higher risk to seabird populations
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	These chemicals can disrupt biological processes The concentration of chemicals – and any associated toxicity – can increase up the food chain Organisms are likely to be exposed to higher levels than what we currently measure Removing chemical additives from plastic won't fully resolve the issue. Recycled plastic and biodegradable plastic also contribute to the problem	Evidence for levels of chemicals associated with plastic pollution around NZ is lacking, with some evidence of POPs and BPA at very low concentration 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
WE DON'T FULLY UNDERSTAND THE IMPACTS CAUSED BY MICROPLASTICS 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	All ecosystems are at risk Species of all sizes are affected We don't know the extent to which plants that we eat are taking up microplastics Microplastics may be spread through the environment via wastewater Leachate from poor quality landfill may contain microplastics that leak into the environment We don't understand the risks from current levels in our environment	Microplastics have been detected in the marine environment in NZ but 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 Immediately reducing litter can minimise future risk The ESR-led MBIE Endeavour Aotearoa Impacts and Mitigation of Microplastics project aims to address many knowledge gaps
WE KNOW LESS ABOUT THE IMPACT OF EVEN SMALLER PLASTIC PARTICLES (NANOPLASTICS) This is a very new field of research and we don't yet understand how pervasive these fragments are in the environment, where they come from, what happens after they are released, and what the impacts are – so we can't yet assess the risks associated with nanoplastics	It is hard to measure nanoplastics It is hard to treat nanoplastics The smaller size may mean fragments move into organs more easily Nanoplastics may have a longer retention time than microplastics The principles of trophic transfer apply	There is the potential for negative impacts associated with these plastic particles to affect our native flora and fauna and taonga species, but because the field of research is new, there is little local evidence The mobility of nanoplastics into tissues provides the potential that they may transfer to the edible tissues of organisms

Impact	The biggest concerns	What it means for Aotearoa New Zealand
PLASTIC POLLUTION POSES A BIOSECURITY RISK 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	Plastic pollution may help spread pathogens and invasive species Ingestion of plastics colonised with microbes may spread pathogens further New or invasive microbial species have the potential to alter whole ecosystems Rafting of organisms poses a threat to global biodiversity	Exotic plant and animal pests that hitchhike on plastic in the sea could threaten NZ's biosecurity A local study has identified plastic debris poses a high risk of transfer for both native species and non-indigenous marine species The main culprit for carrying bio-fouling taxa 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
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 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	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
PLASTIC MAY IMPACT HUMAN HEALTH AND WELLBEING Health impacts are associated with plastic particles and associated chemicals at every stage of its supply chain and life cycle	We don't know how much plastic humans ingest or inhale We don't understand the long-term risks of exposure The consequences to human health from plastics transferred through the food chain are unclear	Our understanding of how much plastic and the different types of plastic people in NZ are exposed to through consumer use, waste management and environmental exposure is very limited With current evidence we cannot infer the risk that plastic poses to the health for people in NZ A few studies have quantified the levels of plastic in local food sources and more studies to quantify the levels of plastic in local food sources are required, particularly for shellfish because people eat the whole animal

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, 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 that is their fate, preventing leakage at source, remediate existing pollution, and sector-specific approaches to mitigate economic impacts. Effective, systemic and enduring mitigation of this environmental harm will include:

- Prevention at source: 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– and the main mechanisms are generally well understood.[24] We currently don't understand the sources, routes, how much and which types of plastic enter the environment in Aotearoa New Zealand.
- Remediate existing plastic pollution: 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. 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. For microplastics or smaller particles, there are no remediation methods currently available that could quickly, efficiently and safely remove these from the environment.
- 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.[25] In that study, the global estimate of the economic impact of marine plastic was around $2.5 trillion each year. In Aotearoa New Zealand we need to consider how plastic pollution will impact our tourism, fisheries and the export industries, among others.

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
- 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
- The characteristics and levels of chemical additives and contaminants associated with plastics in Aotearoa New Zealand and their impacts
- 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, and through leachate
- The downstream impacts on the economy.

[24] Li et al., "Plastic Waste in the Marine Environment: A Review of Sources, Occurrence and Effects,"
[25] Beaumont et al., "Global Ecological, Social and Economic Impacts of Marine Plastic," *Marine Pollution Bulletin* 142 (2019)

5. To what extent can we quantify Aotearoa's plastic? New Zealand's data challenge: key messages

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. 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. 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,[26] 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.

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

A pivotal step to enable Aotearoa New Zealand to reduce our use and mismanagement of plastic is to understand how much plastic we currently use and discard. A baseline material flow analysis is essential to inform and prioritise policy changes and to hold us accountable by measuring improvements over time. 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.

Our analysis has identified how plastics flow through Aotearoa New Zealand, and where data are or should be captured (illustrated in Figure 12 and Table 3). 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. 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.

There are several limitations that currently hinder our understanding of plastic in Aotearoa New Zealand. In many instances data are not collected at all or at a level useful to inform policy decisions around a national action plan for plastics. Data are in silos, making it difficult to understand the flows from product design and use to disposal. Where data have been captured, it is not in a standardised or consistent way, and often measurement is not ongoing. Further limitations are related to accessibility of data. Many commercial entities do have some level of data collection, but most of it is not in the public domain due to commercial sensitivities. Where data have been shared, it has relied on the goodwill of the organisation and has not been independently verified by a third party, and therefore lacks transparency. Finally, even when data are available, much of it does not provide the level of detail that would be most beneficial to inform

[26] The New Plastics Economy Global Commitment is an initiative led by the Ellen MacArthur Foundation and UN Environment where signatories commit to transitioning to a circular economy for plastics by eliminating unnecessary use of plastic, innovating to discontinue use of problematic plastics, and circulating all other plastics through reuse and recycling, and preventing environmental leakage; details available at: http://www.mfe.govt.nz/news-events/new-zealand-signs-international-declaration-cut-plastic-waste.

policy, such as specifying resin type, additives, or recycled content. That level of data will be crucial for identifying the products and material types where we should prioritise changes around use or end-of-life solutions.

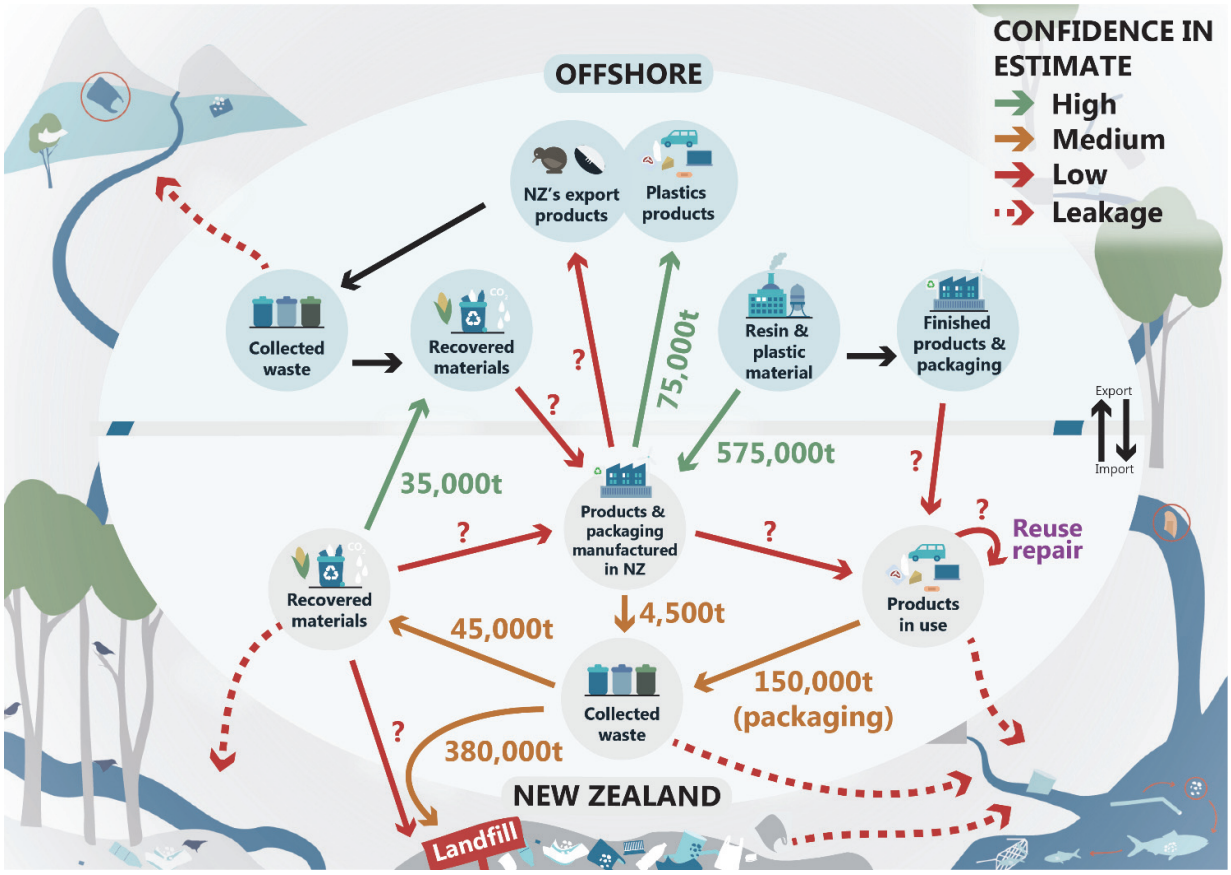

Figure 12 Flows of plastic into and out of Aotearoa New Zealand, including leakage into the environment. Plastic leaking into the environment includes macro and microplastics, and affects land, marine and air environments. It also includes waste that is burned or buried in unregulated landfill. Sources of data are outlined in Table 3.

Table 3 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)[27]	
	Finished products or packaged goods	?	?		Synthetic textiles – 13,000 tonnes
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)[28]	Plastic drink bottles – 25,000 tonnes
	Construction	?	?		350 m^2 residential development – 80 kg mixed plastic waste
	Agriculture	?	?		Waikato and BOP rural properties – 5900 tonnes wraps, covers, films; 1500 tonnes containers, drums
	Other	?	?		
WASTE	Plastic collected for recycling	45,000	Medium	NRRT[29] (2018)	
	Plastic waste landfilled	380,000	Medium	Eunomia (2015) and Perrot et al. (2018)[30]	
	Pre-consumer industrial waste	4,500	Medium~	Plastics NZ (2005)[31]	
LEAKED INTO ENVIRONMENT	Marine litter	?	?		Sustainable Coastlines – average litter density of 411/1,000 m^2 [32]
	Land litter	?	?		Keep New Zealand Beautiful – average litter density 118/1,000 m^2 [33]

[27] Harmonised trade data from Statistics NZ Infoshare
[28] Estimates based on export waste and population/GDP data, not accounting for imported finished products, packaged goods, secondary and tertiary packaging
[29] National Resource Recovery Taskforce estimates based on voluntary reporting
[30] Conservative estimate for landfills based on data for class 1 landfills: 12% (Perrot et al. 2018) by tonnes (Eunomia Consulting)
[31] Based on voluntary manufacturer surveys from 2005
[32] Taken from litterintelligence.org as of 11 November 2019
[33] Keep New Zealand Beautiful, "National Litter Audit", 2019

Plastic imports

For material flow of plastic into Aotearoa New Zealand, we have a clear understanding of the quantity of raw plastic resin imported for onshore manufacture into products as the tonnages and material type are captured by Customs New Zealand and available via Statistics New Zealand. The plastics manufacturing industry (perhaps via the industry body Plastics NZ), should be able to provide comprehensive data on what products are manufactured from imported resin and which sectors are serviced.

In contrast data on the volume and types of plastic that are imported as finished products and packaged goods, including the quantity of plastic used for secondary and tertiary packaging along the supply chain (e.g. carry packs and pallet wraps), has not been collated or publically released. It is likely that the volume of plastic imported in these products is significantly higher than that imported as resin, but with current methods we have no real idea of the scale. Importers of a product should be responsible for reporting weight and types of plastic associated with their imports.

Plastic exports

Our understanding of the quantity of plastic that leaves Aotearoa New Zealand is similarly limited. While there is accurate data on exported tonnes of raw resin, plastic materials and waste plastic, as this is captured by Customs New Zealand, there is no aggregated data on the amount or types of plastic that are exported from Aotearoa New Zealand as products or packaging. A framework for disclosing plastic use at a company or sector level could begin to address the knowledge gaps we have for both import and export data, particularly for finished products and packaged goods.

Plastic in use

We consider the plastic that has been imported into Aotearoa New Zealand and not yet discarded as being in the 'in use' phase. There are little data to draw on to estimate the amount or types of plastic currently in use in Aotearoa New Zealand. Due to the differences in lifetime distribution of how a product is used – i.e. most packaging is single-use but a pipe used in infrastructure may be in use for 100 years – it is pertinent to consider this by sector. Estimates for the scale of plastic packaging consumed nationwide in one year have been made, but not for any other sector such as construction.

Plastic recycling and waste

Once products leave the 'in use' phase they are collected as waste. In Aotearoa New Zealand, the end-of-life options for plastic are recycling or landfill. The vast majority of waste plastic goes to landfill. Various reports have attempted to quantify the amount of plastic collected for recycling and landfill in Aotearoa New Zealand from a variety of data sources, but there is no aggregated national dataset.

One of the key issues limiting our level of understanding around the amount and types of plastic that are recycled or landfilled is the accessibility of data. Whether data are easily accessible is somewhat dictated by the source – household kerbside refuse and recycling data are more often in the public domain because it is collected by councils and sometimes reported in their mandatory waste assessments. In contrast, commercial refuse and recycling is often private and subject to confidentiality agreements or unable to be shared unless aggregated into a larger dataset due to commercial sensitivities.

When data are publicly available, often in council reports, the level of detail is variable. Where material type is reported for recycling, it is generally as PET (#1), HDPE (#2) and other plastics (#3-7). Most data in the public domain do not break down tonnages for each type of plastic #3-7 or by colour for PET (#1) and HDPE (#2) (which affects the likelihood of those plastics being recycled), nor does they tell us which types of plastic commonly contaminate the recycling stream and are then sent to landfill.

There are data on the tonnages of waste to levied landfills, but data for non-levied landfills is sparse, including on-farm disposal and illegal dumping. At a national level, there are estimates of overall tonnage of waste to landfill and the

proportion of total waste that is plastic by waste stream (e.g. household refuse vs construction). Estimates suggest that commercial waste streams make up nearly three quarters of waste to landfill, but these data are often not publicly available. Commercial waste plastic also contains plastic outside the standard resin types used for consumer packaging.

Some studies on the composition of waste to landfill include an estimate of the proportion of plastic waste that could be diverted for recycling, but again this has not been aggregated at a national level and the information that is publically available doesn't include any granularity on the types of plastic or key products represented. This will be partly addressed by a WasteMINZ study auditing a nationally representative sample of household refuse and recycling streams.

Accurate and standardised reporting of the amount and material type of plastic collected for recycling and landfill requires commercial entities to disclose data.

Plastic in the environment

We are particularly limited in our understanding of the quantity of macro, micro and nanoplastic pollution leaking into our environment, and from which sources. A national framework to coordinate and report these data could build on existing research and citizen science efforts.

Urgent need for better data

For the future, data collection is a crucial step towards understanding and reducing negative effects of plastic in Aotearoa New Zealand. To be most effective, we need agreement at a national level to define the problem; prioritise what is recorded and by whom; how this is integrated with other datasets; and how results should drive actions.

A considered, systematic approach to nationwide data collection for plastic is necessary to:

- Identify and quantify the problems related to plastic
- Establish and hold ourselves accountable to targets related to plastic use and waste (such as those in the NZ Plastic Packaging Declaration signed by the Ministry for the Environment)
- Develop appropriate infrastructure to deal with plastics (e.g. recycling facilities)
- Highlight opportunities for the substitution of plastics, removal of unnecessary plastics, creation of reuse models, and establishment of circular solutions for products
- Determine how much plastic is lost to the environment and use this to help build public awareness of the need to prevent plastic pollution
- Provide accurate market information to encourage entrepreneurship in this area
- Determine the environmental impacts across the full life cycle, to support manufacturers and brand owners to make informed decisions around product design
- Enable accurate declaration of waste data to the OECD and other international organisations, to improve our ranking as a wasteful nation and thus protect our reputation
- Forecast Aotearoa New Zealand's future use of plastic in light of changes to population and consumerism dynamics.

FOR THE FUTURE, DATA COLLECTION IS A CRUCIAL STEP TOWARDS UNDERSTANDING AND REDUCING NEGATIVE EFFECTS OF PLASTIC IN AOTEAROA NEW ZEALAND

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