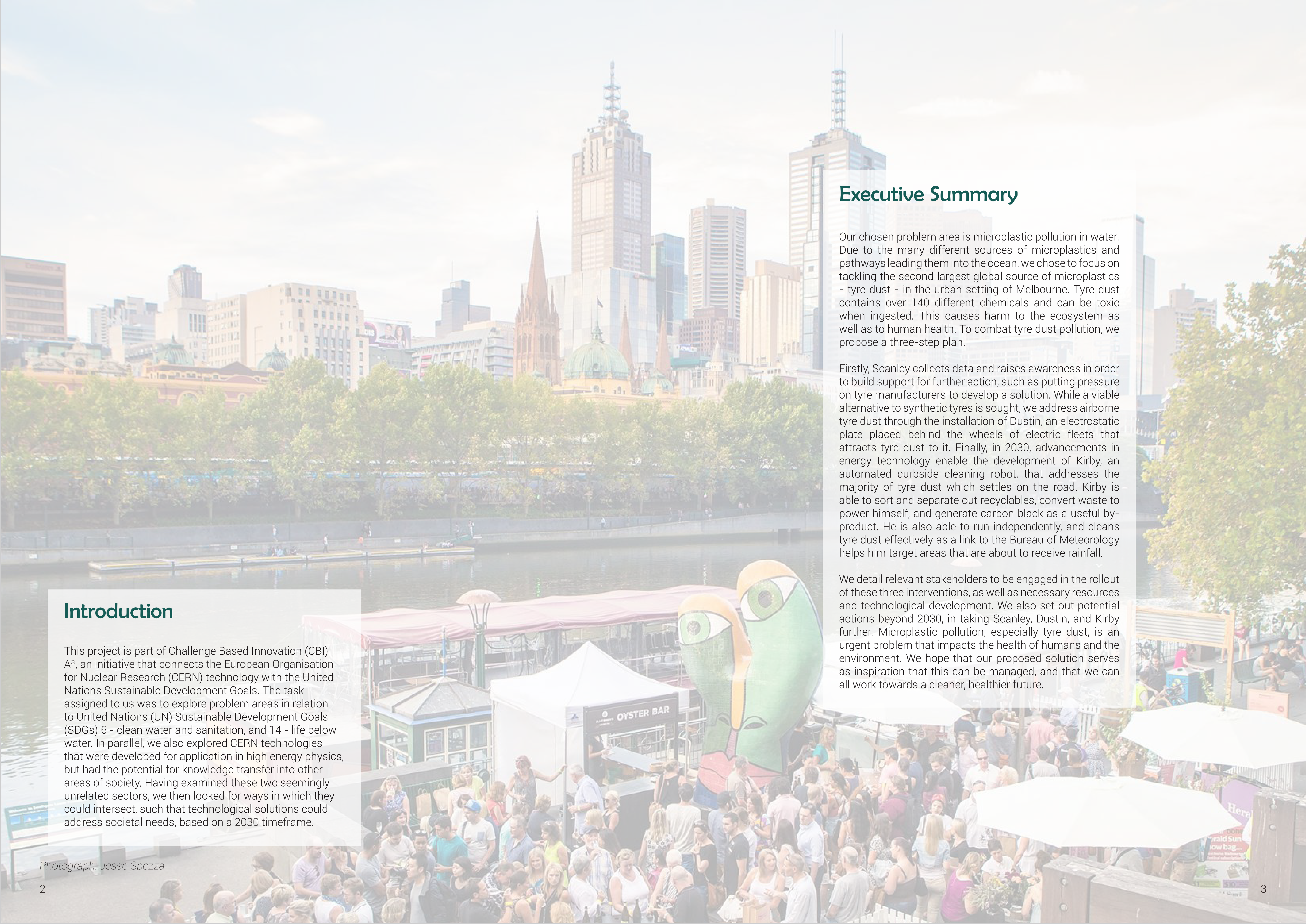
Art: Bonnie Monteleone

Tiny Pieces Big Problem

Tyre Dust in Our Water



Introduction

This project is part of Challenge Based Innovation (CBI) A³, an initiative that connects the European Organisation for Nuclear Research (CERN) technology with the United Nations Sustainable Development Goals. The task assigned to us was to explore problem areas in relation to United Nations (UN) Sustainable Development Goals (SDGs) 6 - clean water and sanitation, and 14 - life below water. In parallel, we also explored CERN technologies that were developed for application in high energy physics, but had the potential for knowledge transfer into other areas of society. Having examined these two seemingly unrelated sectors, we then looked for ways in which they could intersect, such that technological solutions could address societal needs, based on a 2030 timeframe.

Photograph: Jesse Spezza

Executive Summary

Our chosen problem area is microplastic pollution in water. Due to the many different sources of microplastics and pathways leading them into the ocean, we chose to focus on tackling the second largest global source of microplastics - tyre dust - in the urban setting of Melbourne. Tyre dust contains over 140 different chemicals and can be toxic when ingested. This causes harm to the ecosystem as well as to human health. To combat tyre dust pollution, we propose a three-step plan.

Firstly, Scanley collects data and raises awareness in order to build support for further action, such as putting pressure on tyre manufacturers to develop a solution. While a viable alternative to synthetic tyres is sought, we address airborne tyre dust through the installation of Dustin, an electrostatic plate placed behind the wheels of electric fleets that attracts tyre dust to it. Finally, in 2030, advancements in energy technology enable the development of Kirby, an automated curbside cleaning robot, that addresses the majority of tyre dust which settles on the road. Kirby is able to sort and separate out recyclables, convert waste to power himself, and generate carbon black as a useful by-product. He is also able to run independently, and cleans tyre dust effectively as a link to the Bureau of Meteorology helps him target areas that are about to receive rainfall.

We detail relevant stakeholders to be engaged in the rollout of these three interventions, as well as necessary resources and technological development. We also set out potential actions beyond 2030, in taking Scanley, Dustin, and Kirby further. Microplastic pollution, especially tyre dust, is an urgent problem that impacts the health of humans and the environment. We hope that our proposed solution serves as inspiration that this can be managed, and that we can all work towards a cleaner, healthier future.

Kanika Shah

Kanika is almost done with her Masters of Design. Studying and practising interior design in the last 5 years, she is overwhelmed to see how science and design can connect. This project has brought her out of her comfort zone of interior design. Respecting sustainable design, she wishes to establish herself as someone who designs for change for people and their city.

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Jeannie Foo

Jeannie completed her Bachelor of Arts majoring in Political Science and Sociology before pursuing her career in sustainable development. After working for 10 years, she is continuing her education by pursuing a Master of Design Strategy and Innovation. Jeannie is glad that she paid attention in her high school science classes because she would never have imagined getting to "work" in CERN and to be developing ideas using high energy physics!

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Contents

Glossary

Carbon Black
Also known as char, this is a solid by-product of gasification formed from the incomplete combustion of hydrocarbons. Carbon black can be used as a colour pigment in producing inks.

CERN
European Organisation for Nuclear Research consisting of 23 member states. CERN's work aims to uncover the fundamentals of the universe and does this through world class research in high energy physics. CERN technology has sparked innovation in a number of fields, most notably in medicine, space exploration, and information technology.

CERN's Medipix
A chip that works like a camera, taking high-resolution images by detecting and counting each individual particle that hits its pixels. This technology is often used for medical imaging.

CERN's REMUS (Radiation and Environment Monitoring Unified Supervision)
A supervision, control, and data acquisition system initially deveoped to provide radiation protection and environmental impact monitoring to CERN facilities and its immediate surroundings.

CERN's Robotics Software
Software used at CERN to control autonomous movement of robots. These robots are mainly used for detection and maintenance in areas that may be dangerous for humans.

CERN's Structured Laser Beam
A non-diffractive beam that has low divergence - even at distances of hundreds of metres, is very robust to jitter and vibrations, and can self-reconstruct after obstacles. The Structured Laser Beam can be applied in gas detection, medicine, microscopy, metrology, and satellite communication.

CERN's Superconducting Transmission Lines
Electrical transmission line made of magnesium diboride with no resistance, enabling it to transport much higher current densities than ordinary cables without any loss. These lines typically need to operate at a low temperature.

CERN's Thermal Management Materials
Novel advanced materials that can handle the high energy particle beams used in CERN. They combine the thermal and physical properties of diamond or graphite with the electrical and mechanical ones of metals and transition metal-based ceramics.

China's National Sword Policy
Policy adopted by China in January 2018 that imposed restrictions on the importation of recycled materials. As many recycling industries had relied on China as an export market for waste, China's strict contamination limits left recyclers without an end market for their collected waste.

Citizen Science
Scientific research conducted, in whole or in part, by non-professional scientists, typically as part of a collaborative project with professional scientists.

Dustin
Proposed electrostatic plate system fitted behind vehicle wheels to collect airborne tyre dust as it is emitted.

Gasification
The reaction of materials at high temperatures without combustion using heat, pressure, and steam to convert them into synthetic gas.

Kirby
Proposed autonomous curbside-cleaning robot that targets tyre dust and road debris at the sides of the road where they are likely to accumulate, thus preventing them from entering stormwater.

Material Recovery Facility
A specialised processing plant that receives, sorts, and prepares recyclable materials for marketing to end-use manufacturers.

Microplastics
Small, sometimes microscopic fragments of plastic below 5mm in size. These can be generated either as primary microplastics - through the production, use, and maintenance of plastic products, or as secondary microplastics - through the degradation of larger pieces of plastic.

Microwave-assisted Pyrolysis
The application of microwave power for heating at a fast rate. This can be used for pyrolysis, with tests indicating efficient degradation of polymers with this method.

Near-infrared Spectroscopy
The use of near-infrared radiation to excite molecules, causing them to vibrate. On a molecular scale, each material vibrates in its own unique way, enabling it to be identified when compared against a database of known properties.

Scanley
Proposed scanner as part of a citizen science installation to raise awareness of microplastic pollution by using high-resolution X-ray images to reveal microplastics contained in water and living organisms.

Static Electricity (also referred to as Electrostatic)
An imbalance of electric charges within or on the surface of a material caused by the movement of electrons from one material to the other, leaving one positively charged and the other negatively charged. Materials with opposite charges tend to stick to each other.

Stormwater
Surface run-off from rain and storm events that enters the drainage system. Stormwater carries pollutants with it, and this ends up in rivers, creeks, lakes and bays.

Synchrotron Light
Electromagnetic radiation that is emitted when charged particles moving at close to the speed of light are forced to change direction by a magnetic field.

Synthetic Gas (Syngas)
A gaseous product of gasification consisting mainly of carbon monoxide and hydrogen, as well as methane, short hydrocarbon chain gases, and carbon dioxide. Syngas can be combusted for energy generation.

Synthetic Tyres
Most, if not all vehicle tyres are modern pneumatic tyres, generally made of synthetic polymers, namely Styrene Butadiene Rubber (approximately 60%), in a mix with natural rubber and many other additives. They are referred to as synthetic tyres in this document to differentiate them from rubber and metal tyres.

Tyre Dust
Particles that are emitted during the wear and tear of synthetic tyres, mainly when a vehicle brakes or accelerates. Tyre dust is the second largest source of primary microplastics released into the world's oceans.

United Nations' Sustainable Development Goals
A set of 17 global goals and their corresponding targets that form a shared blueprint for a better and more sustainable future for all. This was adopted by all United Nations member states in 2015, who are working to achieve them by 2030.

The Problem

Water is a basic human right yet also our most precious resource.

This resource is under threat from man-made pollutants. Through our research, we have identified microplastics as one of the most harmful and pervasive of pollutants, and one that we are still grappling with understanding the magnitude of. Microplastic pollution affects both UN SDGs 6 and 14. The targets most affected are set out below:

Ensure availability and sustainable management of water and sanitation for all

- 6.1 Access to safe drinking water
- 6.3 Improved water quality through decreased pollution
- 6.6 Protect and restore water-related ecosystems

Conserve and sustainably use the oceans, seas and marine resources for sustainable development

- 14.1 Prevent and significantly reduce marine pollution
- 14.2 Sustainably manage and protect marine and coastal ecosystems

"Once it (plastic)'s in the sea, it doesn't really break down properly – it remains there for decades or even centuries."

Sir David Attenborough (Media Planet 2019)

Plastic was only invented in the late 19th century, but has solidified its place as a mainstay of modern life (Parker 2018).

Our dependency on this cheap and durable material comes at a hidden cost. Scientists are now discovering that the durability that makes plastic so appealing also makes it impossible to be rid of. Unlike natural materials, plastic takes an extremely long time to biodegrade down to its constituent molecules. "Estimates range from 450 years to never" (Parker 2018).

Instead, plastics tend to break up into smaller and smaller fragments, and when these fragments are below 5 millimetres in size, they are called microplastics (Boucher & Friot 2017). There are two types of microplastics, namely primary microplastics – which are "directly released into the environment in the form of small particulates", and secondary microplastics – which originate from the "degradation of larger plastic items" (Boucher & Friot 2017, p. 8).

Of the primary microplastics, there are seven major sources, listed in Figure 1 below. These are mainly generated during the manufacture, use, and maintenance of plastic products.

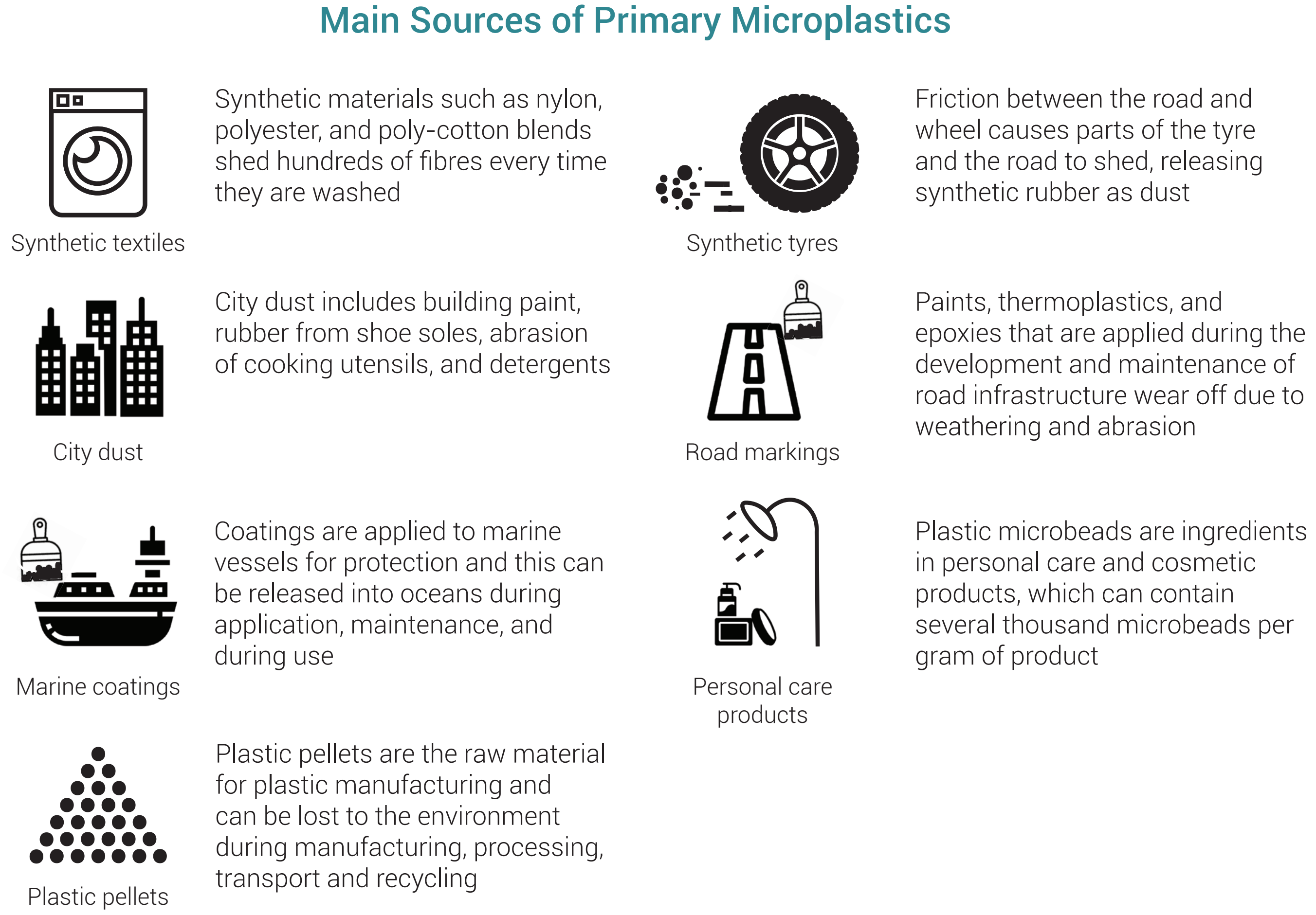


Figure 1: An estimated 1.5 million tons of microplastics are generated per year, more than half of which is from synthetic textiles and tyres (Boucher & Friot 2017)

Zooming in on Tyre Dust

Synthetic tyres are the second largest global source of primary microplastics to the world's oceans. (Boucher & Friot 2017, p. 21).

This is illustrated in Figure 2 below. Tyre dust is generated when the "contact between tyre and road surface causes shear and heat in the tyre" (Kole et al. 2017, p. 3). This causes small tyre particles to be released that, due to the heat, also have road wear particles stuck to them.

Global Releases of Primary Microplastics to the World Oceans

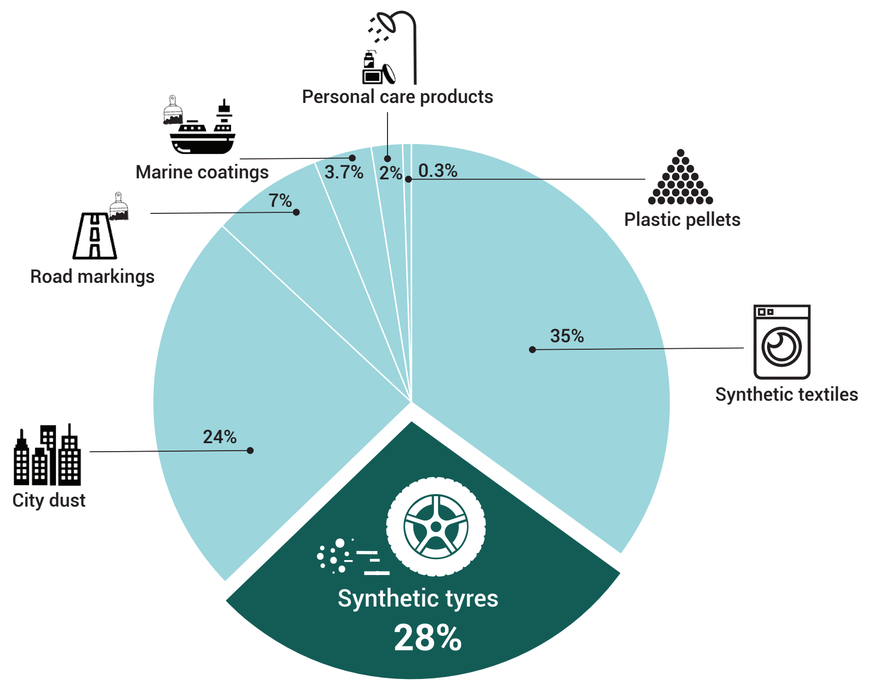


Figure 2: Synthetic tyre dust is the second largest source of primary microplastics to the world's oceans (Boucher & Friot 2017, p. 21)

Tyre wear dust contains over 140 different chemicals

(Working Party on Pollution and Energy (GRPE) 2013, p. 3)

"Tyre wear dust contains more than 140 different chemicals with different toxicity" (Working Party on Pollution and Energy (GRPE) 2013, p. 3), including synthetic rubber, heavy metals, carbon black, and polymers (Adamiec, Jarosz-Krzemińska & Wieszała 2016, p. 369). These chemicals "can have adverse effects on ecosystems by contaminating air, water, and soil" (Adamiec, Jarosz-Krzemińska & Wieszała 2016, p. 368), are considered an "aquatic toxicant" (Kreider et al. 2010, p. 653) and can also cause cancer (Working Party on Pollution and Energy (GRPE) 2013, p. 3).

Tyre dust enters our water sources through run-off from roads, from airborne particles, as well as through stormwater.

Not only does this impact water quality, it also causes plastic to enter our food chain when microorganisms mistake microplastics for food.

> *Ingested microplastic particles can physically damage organs and leach hazardous chemicals—from the hormone-disrupting bisphenol A (BPA) to pesticides—that can compromise immune function and stymie growth and reproduction. Both microplastics and these chemicals may accumulate up the food chain, potentially impacting whole ecosystems, including the health of soils in which we grow our food. Microplastics in the water we drink and the air we breathe can also hit humans directly.*
>
> (Thompson 2018)

Figure 3 below shows three pathways by which microplastics in water can enter human digestive systems, namely through our drinking water, food, and even through table salt.

Pathways for Microplastic Contamination in Water to Carry Toxins into Human Systems

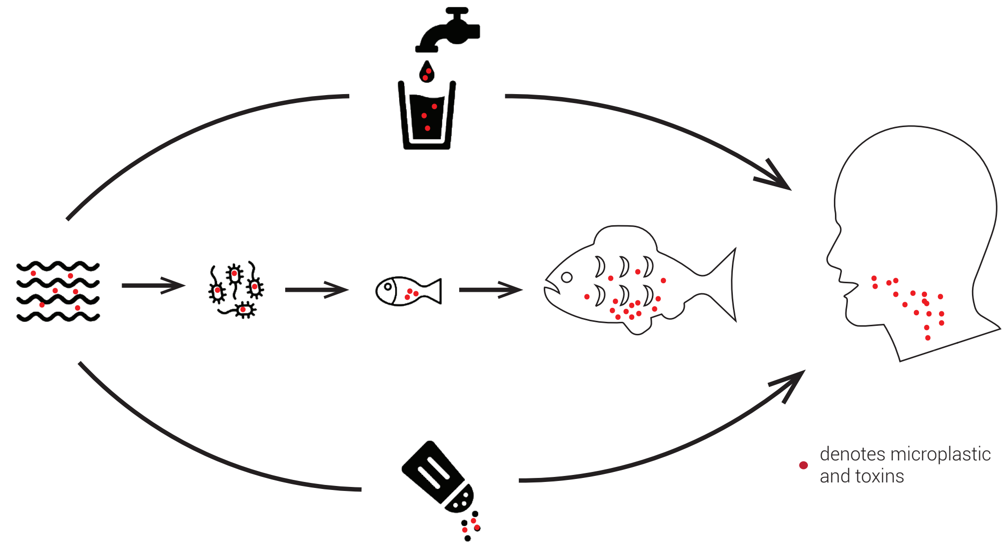


Figure 3: Once microplastics enter water sources, they can be ingested by microorganisms to enter our food chain. They can also be found in drinking water and table salt, thus carrying toxins into human systems.

83% **of worldwide drinking water was found to contain microplastics**

(Lui 2017)

Microplastics are associated with many negative ecological and health issues, and evidence continues to emerge of both the scale and the severity of microplastic pollution. The time to respond to this is now – and this has spurred us to come up with our proposed solution.

Proposed Solution

Combatting Tyre Dust by 2030

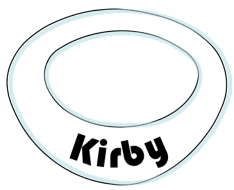
2020

Scanley is part of a citizen science installation located along the banks of Melbourne's Yarra River. Scanley's **high precision scanning** and **material identification** raises awareness of microplastics by making them visible.

2025

Dustin uses **electrostatic attraction** to collect airborne tyre dust. Dustin is installed behind the wheels of electric vehicle fleets to collect dust as its emitted.

2030



Kirby is an **automated curbside cleaning robot** designed to pick up road debris from the curb. He can convert the waste to energy, thus supplementing his power supply.

Melbourne in the Lead Up to 2030

With the implementation of China's National Sword policy in 2018, Australia's waste management industry was thrown in disarray as it lost one of its largest waste export markets (Cansdale 2019). Since then, Australia has grown its domestic capacity to manage waste, with national legislation enacted in 2020 that standardises material recovery and recycling. This is timely, as data continues to emerge about the health and environmental impacts of pollution - particularly plastic pollution - that worsened during the waste crisis, when recyclable materials were piling up unprocessed with nowhere to go (Lasker & Goloubeva 2019). Household waste separation is a key part of the improved waste management process, so material lifecycle, pollution impacts, and the role of individuals is incorporated into the standard school curriculum, driven by the Victorian Waste Education Strategy (Victoria & Department of Premier and Cabinet 2017, p. 93).

In particular, the improvement of scanning and detecting technology has brought microplastic pollution to the fore. As 3D scanning technology is commercialised for medical use, the cost of scanning is reduced enough for it to be incorporated into a public installation raising awareness of microplastics. Scanley is introduced in 2022 as part of a citizen science installation. Scanley opens the public's eyes to the hidden microplastics inside their food and water. The data collected by citizen scientists and marine biologists becomes evidence, and fuels demand for action to deal with microplastics. Amongst measures taken, standards for non-exhaust vehicle emissions are set, and a microplastic emission tax - like the carbon tax of today - is introduced to ensure that source-producing industries take action. The tyre industry pledges to find an alternative to synthetic tyres and to improve labelling of tyres to indicate tyre dust emission rates.

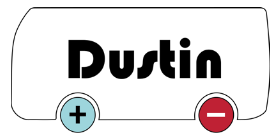
In 2022, the cost of owning an electric car is on par with the cost of owning its internal combustion counterpart (Deloitte LLP 2019, p. 2). Melbourne sees a rise in electric vehicle ownership, including within its public transport fleet as electric buses are rolled out in 2023. Meanwhile, rains are inconsistent and Melbourne dips into its water reserves, so Melbourne Water proposes the use of stormwater recycling to boost water supply. Planning begins for this. As part of their efforts to offset their microplastic emissions, public transport providers install Dustin, the electrostatic dust catchment system on their electric fleets. This includes buses and trams. Incentives are offered for private fleet and vehicle owners to encourage them to install Dustin, and vehicle manufacturers are also encouraged to include this system in new vehicle designs.

In 2026, 3 landfills are permanently closed, and prudent waste management is a core focus (Metropolitan Waste and Resource Recovery Group 2016, p. 43). The need to address this waste issue has driven the advancement of sorting technology, especially in material recovery facilities, as well as waste-to-energy conversion. There is noticeable improvement in Melbourne's air quality, driven by increased public transport use coupled with more vehicles adopting Dustin. Stormwater recycling is piloted, and this reveals the high cost of water treatment due to the contaminants from urban run-off. To reduce this cost, policies are put in place to improve stormwater cleanliness. One of these initiatives is the pilot of Kirby, an automated curbside cleaning robot that targets tyre dust and road debris before it can reach water sources. With evidence that Kirby reduces levels of stormwater contamination, multiple units are set for rollout across inner city Melbourne in 2030.

These events are illustrated in the timeline, Figure 4 on the following pages.

Melbourne in the Lead Up to 2030

Year	Political	Environmental	Social	Technological	Legal	Economic
2020			Emerging data about health and environmental impacts of plastic pollution.		Tightening of local waste management legislation due to National Sword policy	
2021			Plastic pollution, including microplastics, part of standard school curriculum	Cost of colour X-ray scanning technology reduced		
2022	**Scanley - awareness-raising scanner** as part of a citizen science installation					Price parity of electric cars with fuel vehicles
2023	Electric bus fleets introduced in Melbourne	Rise in air and water pollution levels	Public demand for action on microplastics	Significant advancements in waste sorting technology	Legislation and standards set for non-exhaust vehicle emissions.	
2024	Melbourne Water proposes stormwater recycling for domestic use	Increased incidences of extreme weather - water scarcity and droughts		Tyre manufacturers pledge to develop alternative to synthetic tyres	Microplastic emissions tax introduced.	
2025	**Dustin** - **electrostatic dust catchment** - installed on electric vehicle and tram fleets					
2026	Closure of 3 landfills mean space for waste management is critical				Incentives for private owners and vehicle manufacturers to install Dustin	
2027	City of Melbourne pilots stormwater recycling for domestic use		Improved air quality index in Melbourne city centre	Significant advancements in waste-to-energy technology		
2028	Pilot of **Kirby** - the **automated curbside cleaning robot**				Stormwater cleanliness policies driven by stormwater recycling needs	
2029		Reduced levels of stormwater contamination				
2030	**Kirby** rollout across **inner city Melbourne**					
Beyond	Discovery of a viable alternative to synthetic rubber tyres Kirby and Dustin continue to pick up harmful contaminants					



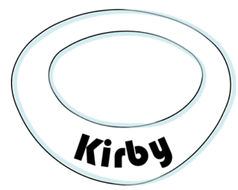


Figure 4: Timeline indicating political, environmental, social, technological, legal, and economic circumstances that set the context for our 3-stage solution

2022

The Awareness-Raising Scanner

Scanley reveals the microplastics hidden in water. Using CERN's Medipix technology, Scanley generates very detailed X-ray images. He also detects and identifies the chemical composition of materials contained in samples, highlighting their microplastic content.

Figure 5: Scanley is part of a citizen science installation along the banks of the Yarra that raises awareness of microplastics

Scanley is a scanning and imaging machine that is able to create highly detailed X-ray images and detect different materials within a sample. It is planned as part of a citizen science installation situated in the city centre by the banks of the Yarra River. This installation aims to raise awareness about microplastics and their impacts on humans and ecosystems.

As Scanley will be in an open public area, its housing is made of high quality recycled plastic that is weatherproof against rain and heat. This carries the message that recycled plastic can be part of the solution, and provides an end market for recycled plastic. Scanley is powered through a public power point.

Visitors to the installation can bring their own samples of water, such as from different parts of the river or from taps in their homes, to be scanned. Samples of water that visitors bring are poured into petri dishes provided to them, which is then placed into a scanning slot. Scanley will reveal the microscopic world inside the water using detectors located in the slot that are specially calibrated to highlight microplastic particles. This is displayed on Scanley's screen.

Visitors are required to input data about the water source of their samples, thus contributing towards a database that tracks water quality across the region. This can help scientists identify the contaminants that are prevalent in different areas.

Aside from scanning water, Scanley can also be used to analyse living organisms without harming them. Thus, marine biologists can scan fish and other organisms within the Yarra River daily. This helps to track the amount of plastic pollution and gather data as well as evidence showing the urgency of the problem.Visitors are also able to view these daily scans via Scanley and see the progress, or decline, of plastic pollution levels in the river.

All this data will be available on a website that serves as an information portal for visitors who want to continue their engagement beyond physically visiting the installation. With microplastics and its impacts included as part of the education curriculum, Scanley and the aforementioned website can serve as teaching aids.

Technology

Scanley is built on CERN's Medipix technology, which is used for particle imaging and detection. Medipix works like a camera which takes images by detecting and counting each individual particle that hits the pixels when its electronic shutter is open (CERN 2018b). The resulting images are high-resolution, high-contrast, and very reliable (Muller 2018).

In particular, the application of Medipix3 in Scanley is akin to its application in the 3D scanner developed by MARS Bioimaging Ltd., which produces colour X-rays by coupling "spectroscopic information generated by the Medipix3 enabled detector with powerful algorithms to generate 3D images" (Muller 2018). Figure 6 shows a colour X-ray generated with this technology.

Where MARS' 3D scanner detects different components of body parts, Scanley detects different materials within water and organisms, highlighting foreign particles such as plastics which are differentiated through their different "energy levels of the X-ray photons as recorded by the detector" (Muller 2018). Figures 7 and 8 show mock-ups of scans and results produced by Scanley.

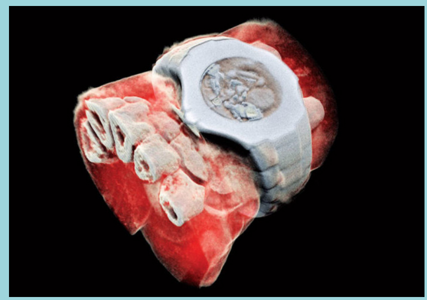


Figure 6: The first 3D colour X-ray image of a human body generated by MARS Bioimaging Ltd. combines spectroscopic information with data analysis to produce 3D images (CERN 2018a)

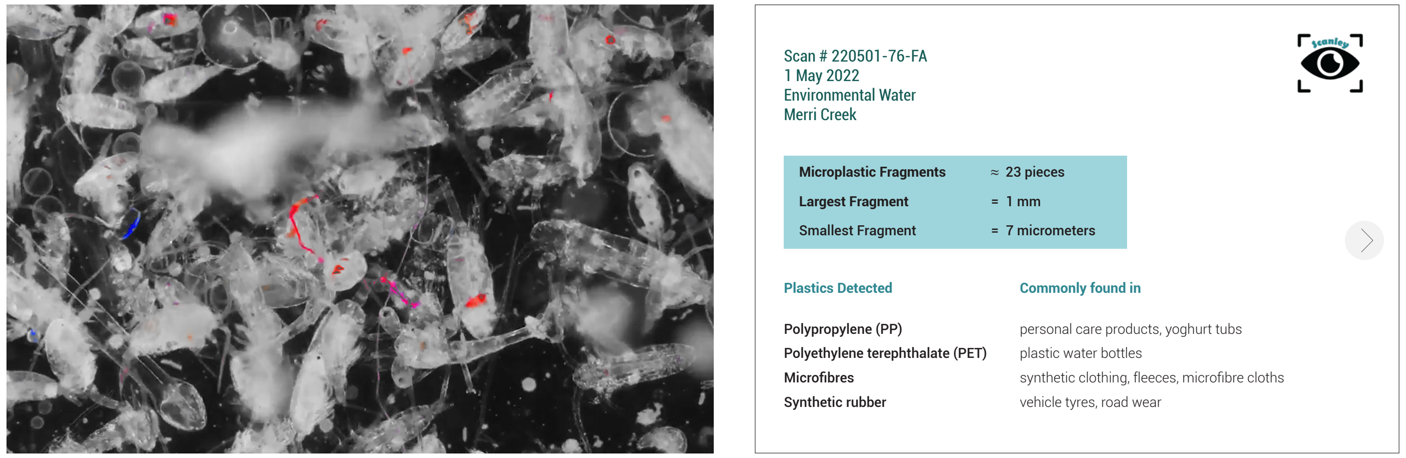


Figure 7: Mock-up image of river water where microplastics have been highlighted in red and blue (L) and sample scan results (R)

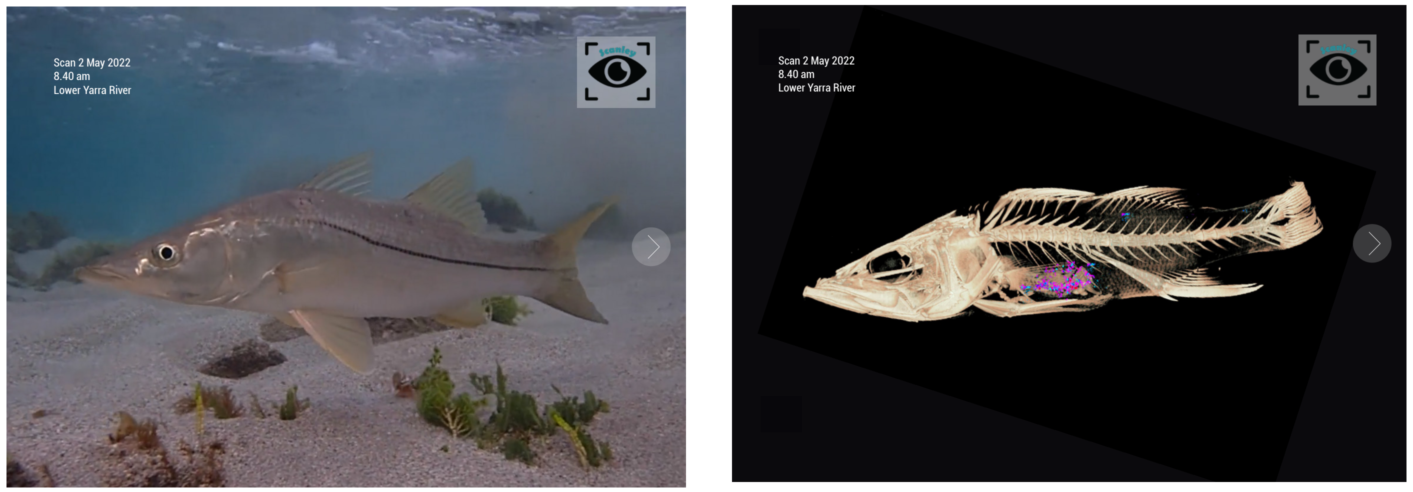


Figure 8: Mock-up scan of river fish - fish in the environment (L) and scan where microplastics are highlighted in fluorescent colours (R)

Value Proposition

Scanley can show visitors first-hand the microplastics that are hidden in water. They are encouraged to bring their own samples to build greater trust in the results, as visitors are conducting their own tests and not relying on prepared samples. Engaging Melbournians as citizen scientists to contribute data towards a larger body of evidence also builds their connection to the river and ownership over the problem. Further, having information on microplastics and their impacts in a visible and accessible location helps to bring the topic to the fore. Plastic pollution can be included into the education curriculum, embedded into subjects such as Science, Geography, Technologies, and Health and Physical Education. The citizen science installation and accompanying website then serve as teaching aids to bring these topics to life.

The data and evidence collected through Scanley can be used by marine biologists, scientists, non-governmental organisations, and environmental bodies such as the Department of Environment, Land, Water and Planning and the Environmental Protection Authority Victoria to push for further action on microplastic pollution. This sets the stage for tougher regulation on microplastics, particularly amongst players in source industries such as synthetic clothing manufacturers, tyre manufacturers, and plastic producers. It also creates impetus for the rollout of initiatives to curb microplastic emissions.

Figure 9: As part of their curriculum, schoolgroups can be encouraged to visit the installation, thus bringing the knowledge home to their families

2022

Stakeholder Map and Implementation Plan

Influence ↑ / Interest →

Businesses at the riverfront Local councils along the Yarra River	City of Melbourne Melbourne Water Environmental Protection Authority Victoria Department of Environment, Land, Water and Planning Sustainability Victoria Parks Victoria
VicRoads Medipix Collaboration community	Schools/education groups Marine biologists Non-governmental Organisations Traditional Owners Public Volunteers

Figure 10: Stakeholder map of parties related to Scanley's implementation

Scanley and the citizen science installation can be funded through government grants such as:

- Citizen Science Grants offered by business.gov.au that support community participation in scientific research projects that have a national impact (Australian Government 2018)
- Port Phillip Bay Fund offered by the Department of Environment, Land, Water and Planning that supports projects addressing local and regional priorities to protect the health of the Bay (State Government of Victoria 2019)
- Litter Innovation Fund offered by Sustainability Victoria that funds innovative approaches that prevent and reduce the impact of litter and illegal dumping (Sustainability Victoria 2019)

This funding can support the adaptation of CERN's Medipix technology for environmental scanning purposes, from its current mass adoption in the medical imaging industry. Advancements in the medical imaging field will also help to bring down the cost of the scanning technology as a whole, making the installation more commercially viable. The more education-oriented funds can be utilised to support the cost of the citizen science installation for a proposed 2 year period.

Marine biologists can be supported by Melbourne Water to study the health of water and marine species, supplementing the river health and monitoring work they already conduct (Melbourne Water 2017). Volunteers from various non-governmental organisations (NGOs) as well as employees of Environmental Protection Authority Victoria, Sustainability Victoria, and the Department of Environment, Land, Water and Planning can monitor and maintain Scanley. With these stakeholders coming together, Scanley can be introduced at more public spots. As knowledge about microplastics grows, more NGOs and local councils along the Yarra River can take over the stewardship of their local installation, and amend the content to suit their locality.

Scanley opens the public's eyes to the hidden microplastics inside their food and water. The data collected by citizen scientists and marine biologists becomes evidence, and fuels demand for action to deal with microplastics.

Image Source: School Strike 4 Climate 2019

Dustin

The Electrostatic Plate Collecting Airborne Dust

Dustin is a system consisting of an electrostatic plate, a vacuum suction system, and a dust collection chamber. This is fitted behind the wheel below the undercarriage of the vehicle to attract and capture tyre dust.

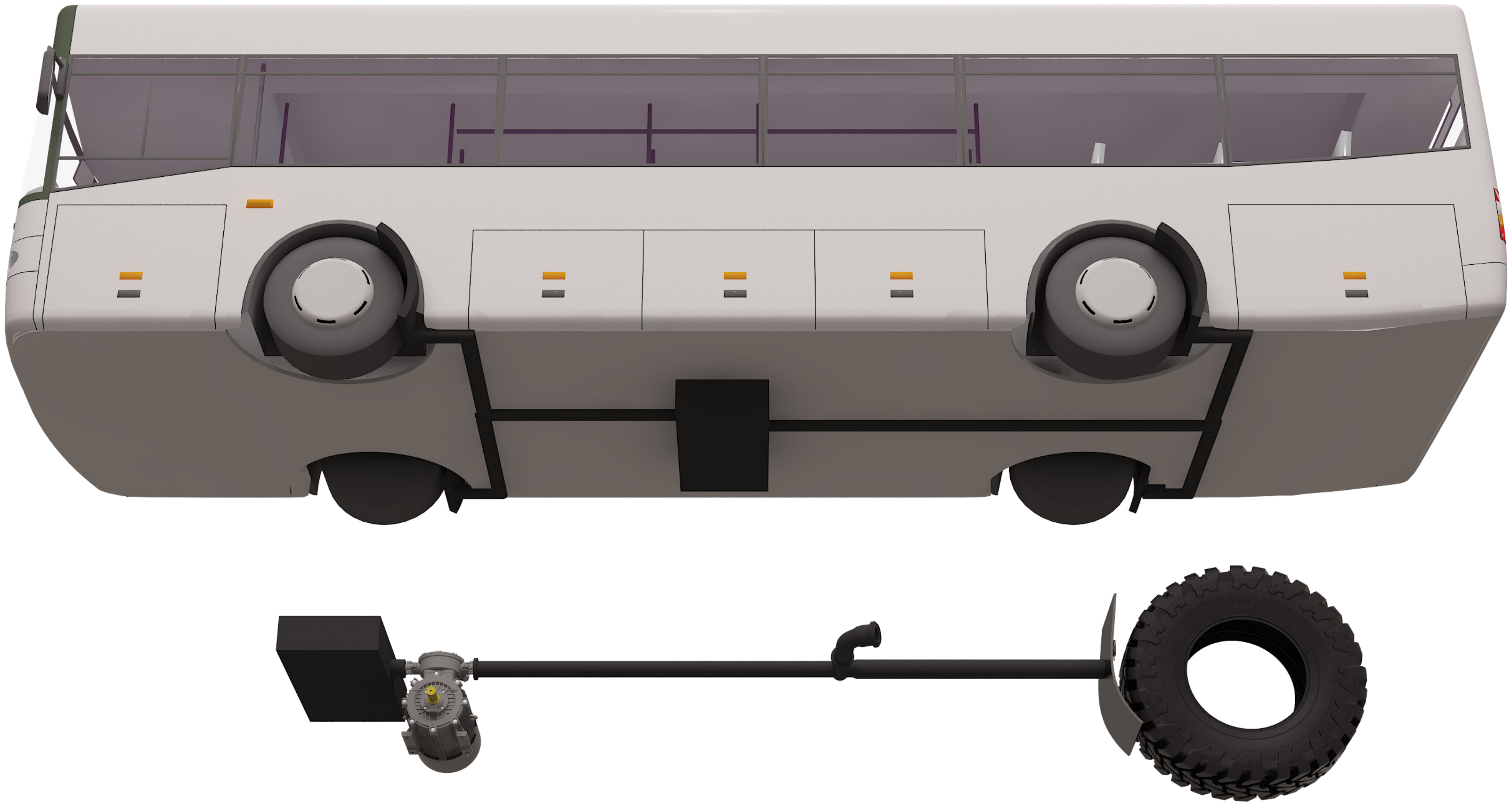


Figure 11: Dustin is an electrostatic plate that can be fitted on the undercarriage of electric fleets to collect airborne tyre dust as it is emitted

Tyre dust is emitted every time a vehicle brakes and accelerates. Some of these dust particles are so small that they become airborne, staying "in the air for minutes to hours and typically travel(ing) distances varying from (a) hundred meters to as much as 50 km" (Kole et al. 2017, p. 1265).

Kole et al. (2017, p. 1265) estimate that 12% of tyre dust is emitted to air, which can end up in surface waters or be inhaled by humans and animals, thereby causing health problems. To reduce the amount that is emitted to the environment, Dustin is fitted behind the wheel to act as a magnet for these airborne particles.

Dustin uses CERN's superconducting transmission lines to carry electricity efficiently from the vehicle battery to the electrostatic plate system. This reduces energy losses, minimising impact on the vehicle's normal operation.

Dustin would initially be retrofitted onto public electric fleets such as buses and trams. Government incentives can encourage the installation of Dustin in private fleets such as taxis and car-sharing services, as well as by private vehicle owners. Vehicle manufacturers can also be incentivised to include Dustin as a standard component in the design of new vehicles.

An estimated

12%

of tyre dust is airborne when emitted

(Kole et al. 2017)

Technology

Dustin works on the principles of static electricity. Tyre dust is negatively charged when released due to the friction between the road and the wheel.

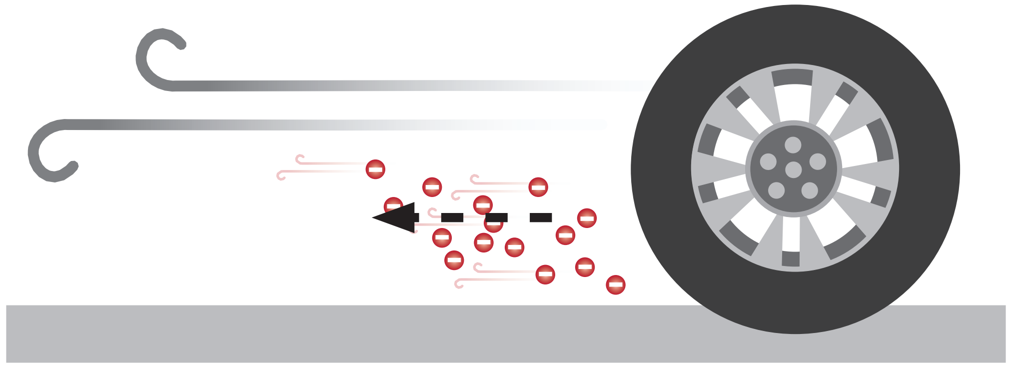


Figure 12: Tyre dust is negatively charged as it is released

A plate made of carbon steel is installed behind each wheel. This plate is positively charged due to the application of a high voltage, supplied by the vehicle's battery and carried by CERN's Superconducting Transmission Lines. These lines are able to transport "vast quantities of electrical current... within a pipe of a relatively small diameter" and with minimal energy losses (Monnin 2019), thus serving as an efficient means of power transmission. As the laws of static electricity dictate that opposites attract, the negatively charged tyre dust particles stick to the positively charged plate.

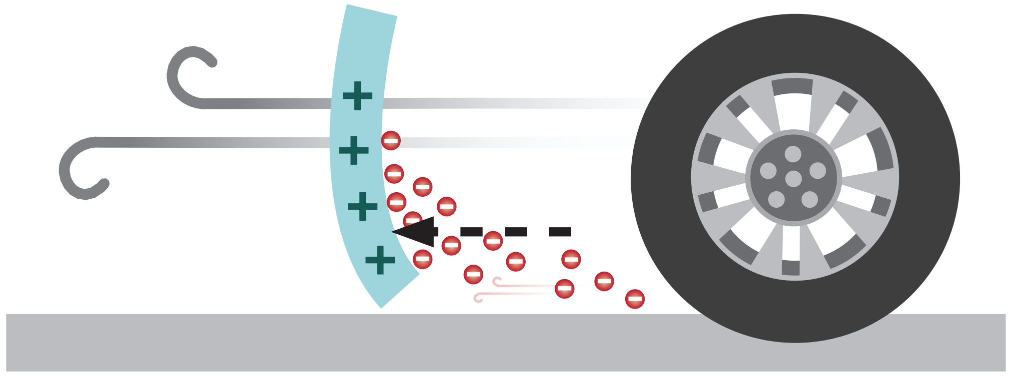


Figure 13: The negatively charged tyre dust is attracted to the positively charged plate

Once the vehicle's engine is turned off, a vibration motor located behind the plate is activated. This shakes off the particles that are stuck to the plate, and a vacuum motor is activated to suck the dust into a collection chamber installed at the vehicle's undercarriage. This metal chamber, approximately 25cm^2 and 10 cm high, is emptied and maintained during regular servicing of the vehicle by workshop technicians. The tyre dust is then disposed of in landfill, until other uses for it can be developed, such as for construction or conversion into ink.

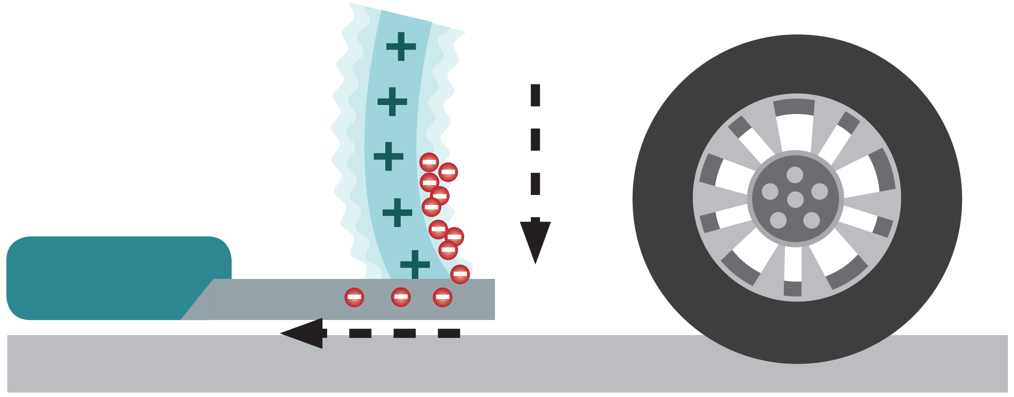


Figure 14: A vibration motor shakes off the particles to be vacuumed into a chamber

Value Proposition

With Dustin installed on vehicles, tyre dust can be picked up at point of emission. Dustin targets the 12% of airborne tyre dust, as well as lesser portions of heavier particles that may otherwise fall to the road surface (Kole et al. 2017, p. 1265). While vehicle exhaust emissions have been the focus of many regulations and policies, the contribution of non-exhaust vehicle emissions is significant. A study carried out in Moscow showed that "the core pollutant of the city air (up to 60% of hazardous matter) is the rubber of automobile tyre used up in a small dust" (Working Party on Pollution and Energy (GRPE) 2013, p. 1).

Research shows that air at a highway with moderate traffic contains:

> *between 3,800 and 6,900 tyre particles per cubic meter of air while more than 58% of them are under 10 microns in size and therefore are able to penetrate into human lungs causing bronchial asthma, allergic reactions, as a result of skin and mucosa contact – rhinitis, conjunctivitis and urticaria. Such tyre particles almost cannot be excreted from the body.*
>
> (Working Party on Pollution and Energy (GRPE) 2013, p. 1)

Thus, not only would Dustin be contributing towards reducing the amount of tyre dust entering stormwater but would also reduce the amount of tyre dust released into air. This would have a positive impact on air quality, leading to less respiratory health problems, both for humans and for living organisms. Improved air quality will lead to ripple effects such as lower health service costs, improved tourism rates, and an overall healthier ecosystem.

Dustin will also enable the companies that install it to reduce their overall carbon and microplastic emissions. This could potentially offset their carbon footprint, which may result in financial benefits, apart from also improving their sustainability rating and public perception.

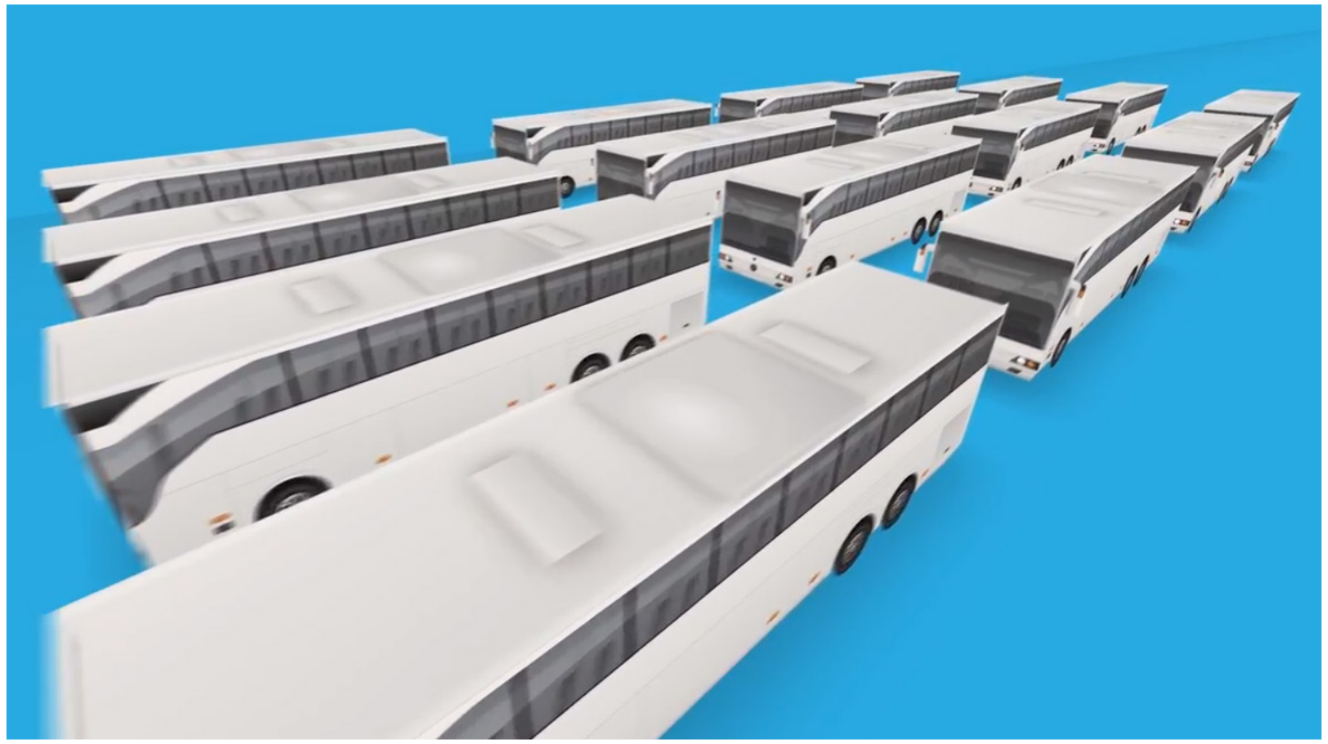


Figure 15: Dustin could be installed on vehicle fleets to help companies offset their vehicle emissions

Stakeholder Map and Implementation Plan

Influence		
	Private vehicle owners Private fleet owners	Public Transport Victoria (PTV) Road Transport Authority Vehicle manufacturers City of Melbourne Department of Environment, Land, Water and Planning Sustainability Victoria
	Waste collection services Waste management facilities Vehicle owners	Environmental Protection Authority Victoria Melbourne Water Fleet service and workshop stations Tyre manufacturers
		Interest

Figure 16: Stakeholder map of relevant parties for Dustin's development and adoption

Dustin can be produced by a private company that is working towards reducing tyre dust emissions. The development costs can be funded through programs such as the Social Impact Investment for Sustainability program offered by Sustainability Victoria that offers a grant and low interest loan to investment-ready social enterprises that work to avoid and recover waste and improve resource efficiency in the Victorian community (Sustainability Victoria 2019b).

Research will have to be conducted to obtain accurate data on tyre dust emission amounts, as current studies have widely varying estimates. CERN's Superconducting Transmission Line technology will also require further adaptation, as it is currently geared towards supplying whole cities, and requires extreme cooling. However, the same technology applied on a small scale can foreseeably achieve efficiencies at room temperature. The safety of electrostatic systems as well as their ability to function in humid conditions will also need further investigation.

Once Dustin has received approval for rollout from the Road Transport Authority, it can be purchased by Public Transport Victoria to be fitted onto public electric fleets, namely buses and trams. This contributes towards the City of Melbourne's target of net zero emissions by 2050 (State Government of Victoria 2018). Workshop technicians will be trained to empty the tyre dust collection chambers as part of regular vehicle maintenance.

The Department of Environment, Land, Water and Planning can incentivise the installation of Dustin on private vehicles by offering tax deductions. This will be especially effective if taken up by private companies with electric vehicle fleets, for example delivery trucks, taxis, and car-sharing vehicles. Eventually, the introduction of a microplastics emissions tax will make it more costly to own a vehicle without Dustin installed. This also pushes vehicle manufacturers to incorporate Dustin as a standard component in all new vehicles.

Melbourne sees a rise in electric vehicle ownership, including within its public transport fleet. As part of their efforts to offset their microplastic emissions, public transport providers install Dustin, the electrostatic dust catchment system on their electric fleets.

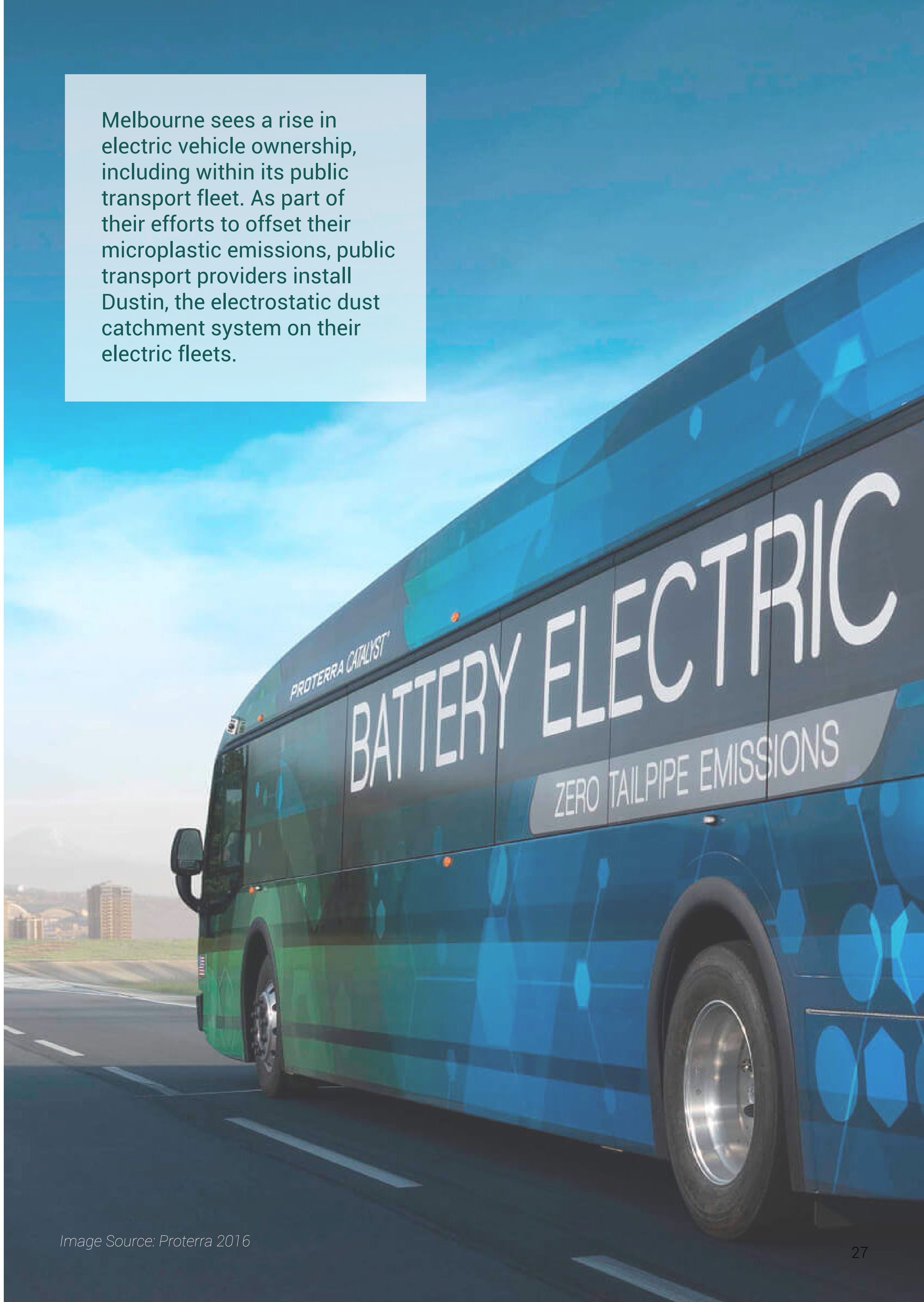


Image Source: Proterra 2016

2030

The Automated Curbside Cleaning Robot

Kirby picks up tyre dust and other small road debris to prevent them from entering our water sources. He sorts the waste, separating out recyclables and converting the rest into Syngas through gasification. His carbon black by-product can be converted into ink. Kirby uses the weather forecast to target areas about to receive rainfall, and can share weather-related information.

Figure 17: Kirby navigates the city autonomously, picking up tyre dust and road debris at the curbside to prevent it from entering stormwater drains

Kirby is an autonomous robot that is purpose-built to clean up tyre dust and smaller road debris from curbs. He is made of high quality recycled plastic that is weather-proof and durable, serving to demonstrate the value of reused materials as well as providing an end market for recycled materials, a challenge for many material recovery operations (The State of Victoria Department of Environment, Land, Water and Planning 2018).

Kirby is designed to move along the pavement on omni wheels while his soft robotic arm vacuums the curb - where the majority of tyre dust accumulates (Cadle & Williams 1978, p. 505). This prevents tyre dust from being washed into water systems through stormwater and urban run-off.

Kirby supplements street sweeping activities, which focus on the melted tyre rubber in the middle of the road, as well as the work done by Dustin in picking up airborne tyre dust at point of emission.

Kirby was designed to pick up road debris before it enters stormwater and surface waters based on evidence that "pollutant source control is a more efficient practice than allowing materials to traverse further into the storm sewer system or receiving water where removal is often more costly and less efficient" (Schilling 2005, p. 11). As he uses gasification to process the waste to energy, his cleaning activity helps to supplement his own operation.

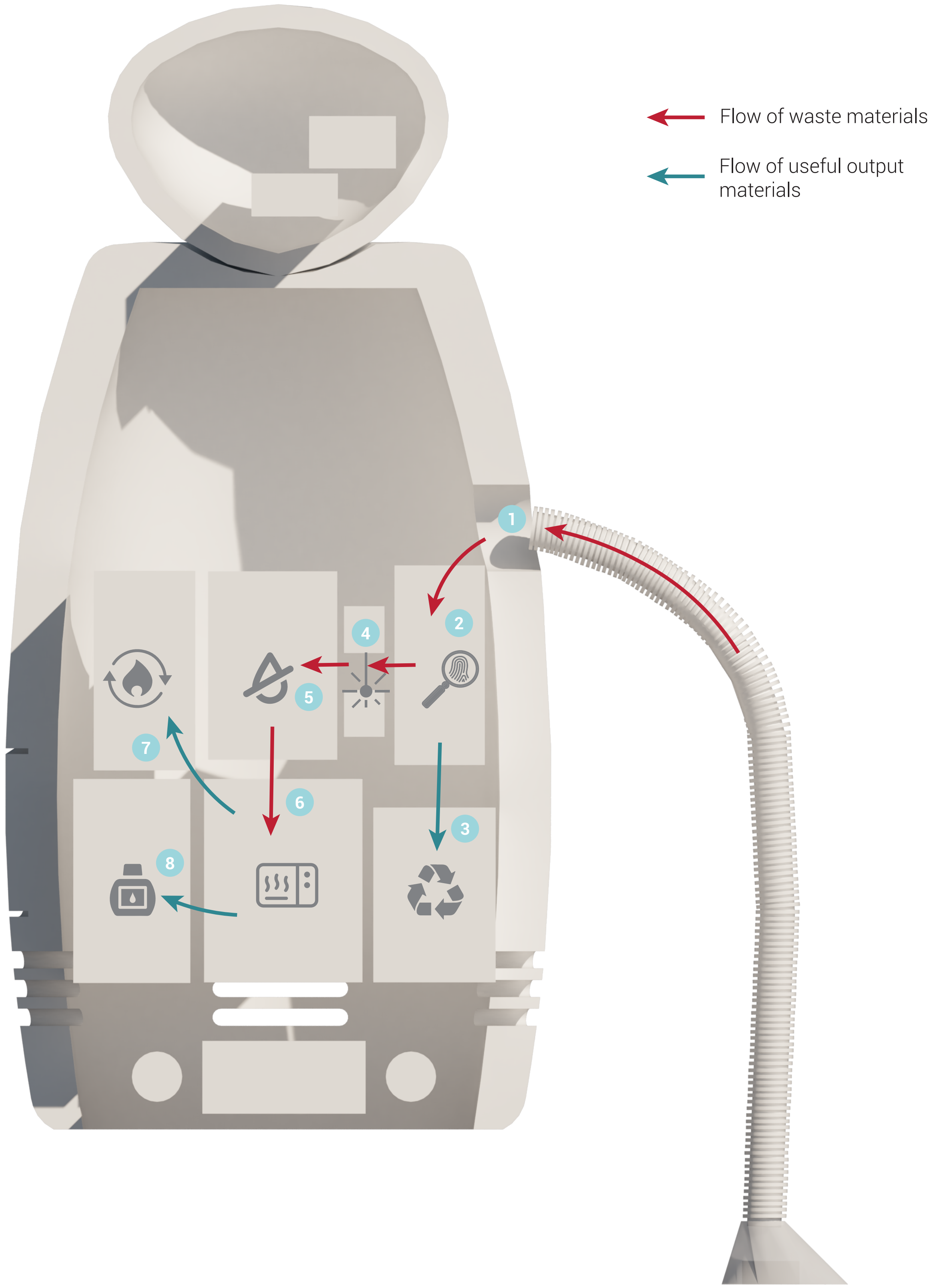


Figure 18: Flow of materials through Kirby where red arrows indicate waste materials and green arrows indicate useful output materials

2030

Technology

Kirby uses his array of navigational sensors to independently navigate the city streets. Aside from completing a set route, Kirby can modify the path he takes depending on input from the Bureau of Meteorology, which helps him identify areas about to receive rainfall and thus which are high priority targets to prevent pollutants entering stormwater runoff.

As Kirby is linked to the Bureau of Meteorology, he can display weather-related information on his interface. Melbournians can check the weather forecast and view the air quality index so that they can equip themselves appropriately. This information is displayed on a glass screen that forms his 'face'. Pedestrians can interact with Kirby to access this information.

Kirby's soft robotic arm is made of a flexible silicon material to ensure that he does not damage or harm anything in his way. The arm is also extendable, so it can move around obstacles and in hard-to-reach places. The arm is controlled using CERN's Robotics Software, commonly used to manage autonomous movement (CERN 2018c).

1. A vacuum motor sucks tyre dust and other road debris up the robotic arm and into Kirby.

2. Once the waste has entered Kirby, it is sorted using a near-infrared spectroscope. Near-infrared spectroscopy is based on detecting the vibrations of atoms within molecules that have been exposed to infrared radiation (Stuart 2005). Infrared radiation is part of the spectrum of synchrotron light produced during particle acceleration, and is used by CERN and others. For example, it can be used for material identification, such as in food quality monitoring and at material recovery facilities.

3. Like in material recovery facilities, the near-infrared spectroscope detects and sorts out recyclables such as metals and glass, to be deposited into the recyclables collection chamber. Kirby will empty this chamber into public recycling bins when he detects that it is full, by reversing the suction of his robotic arm.

4. The rest of the waste is channelled through a series of laser beams to be shredded into small, uniform pieces. These laser beams use CERN's Structured Laser Beam technology which "has the potential to greatly improve a number of mainstream applications using laser beams or light beams" (CERN 2018d). These lasers have a compact spot size, are very robust, and can run at lower costs.

5. After shredding, these uniform particles move on to the dehydration chamber, where heat and air flow is used to remove excess moisture from the waste. Dehydration helps not only to lower the overall weight of the waste but also to prepare it for more efficient gasification. In one study, the heating process was much quicker in the absence of water, which tended to negatively affect the performance of catalysts used (Wong et al. 2015, p. 1176).

6. After dehydration, the waste is moved into the gasification chamber, made of CERN's metal matrix composite, one of its Thermal Management Materials. These materials combine the thermal and physical properties of diamond with the electrical and mechanical ones of metals. They "possess low density, high thermal conductivity, low coefficient of thermal expansion, high operating temperature and excellent thermal shock resistance (CERN 2018e), making them suitable to withstand the high temperatures required for gasification. These high temperatures are achieved through microwave-assisted pyrolysis, which has a fast heating rate and is cost-effective (Wong et al. 2015, p. 1170). Studies have shown that microwave-assisted pyrolysis can convert commingled polymer waste, agricultural waste and tyre waste into fuel (Wong et al. 2015, p. 1171).

7. One by-product of gasification is synthetic gas (Syngas), which consists mainly of carbon monoxide and hydrogen (Fahmy et al. 2018) and can be combusted to drive Kirby's movement (Fabry et al. 2013, p. 425). This supplements the power supply from his battery, which Kirby can charge wirelessly at public power points.

8. The second by-product of gasification is carbon black. When the carbon black chamber is full, Kirby deposits the carbon black at community centres such as libraries and post offices to be processed into ink. A similar technology already exists, developed by Graviky Labs Pvt Ltd., where soot present in vehicle exhaust fumes is harvested and converted into ink (Graviky Labs Pvt Ltd. 2015).

Kirby's Internal Components

indicates a CERN technology (Ideas)

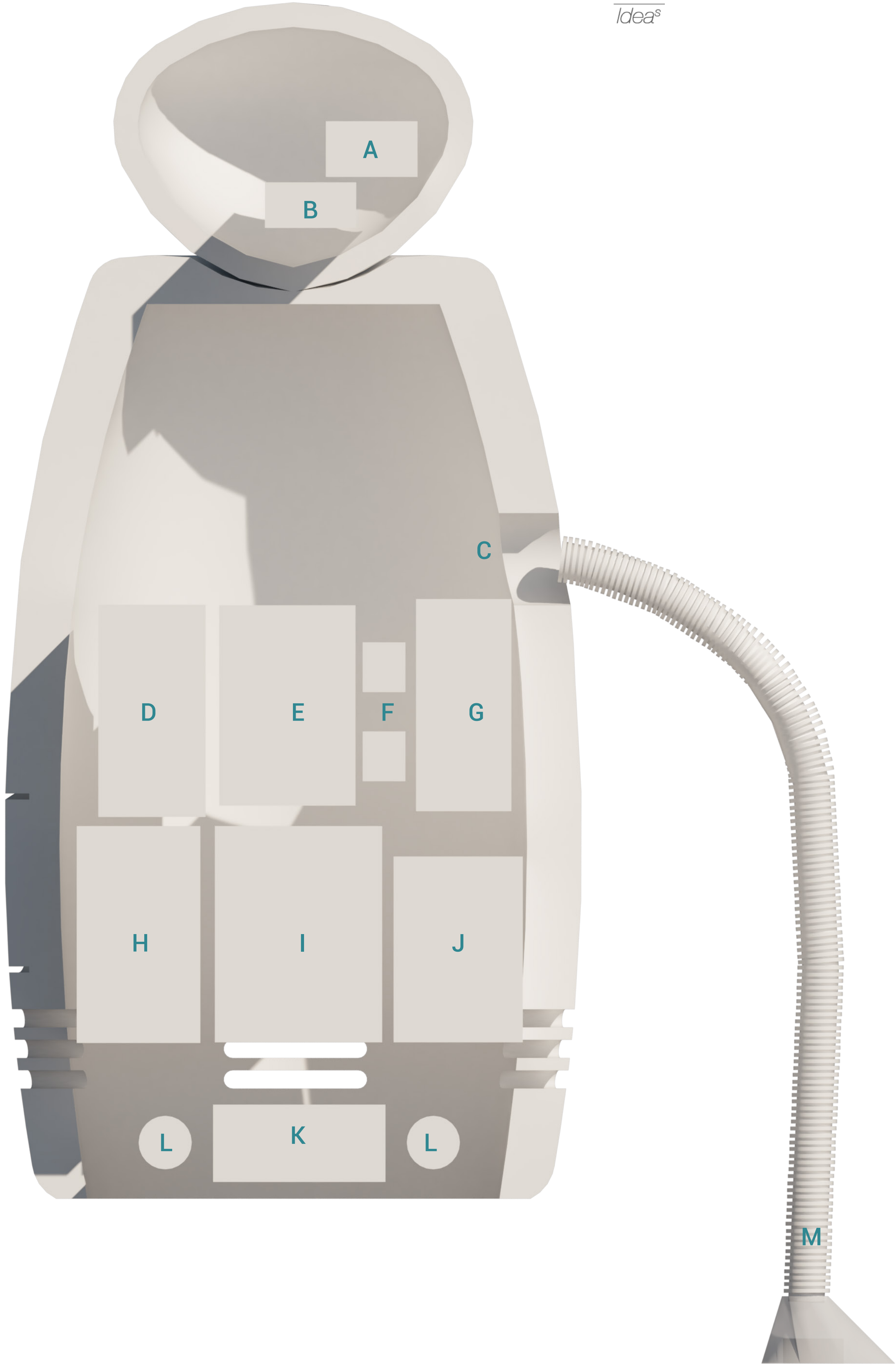


Figure 19: Diagram of components within Kirby with explanations of the their technology and function

2030 Kirby

A Battery

Kirby's main power source is a battery placed inside his 'head'. This is supplemented by the syngas produced from the gasification of waste materials. When low on power, Kirby is able to wirelessly charge himself at public power points along his route.

B Central Intelligence

Kirby's 'brain' runs CERN's data management and analysis software - REMUS. REMUS is able to process the vast amounts of data from Kirby's sensors, enabling him to manage the sorting and gasification operations, intelligently plan his cleaning route, and be remotely controlled and monitored by technicians.
Kirby also receives weather information from the Bureau of Meteorology that helps him target areas about to receive rainfall, thus reducing stormwater runoff. Kirby can provide weather information to pedestrians via his display.

Robotics Software

CERN's Robotics Software has been integrated to control Kirby's soft robotics arm as well as his autonomous navigation.

C Vacuum Motor

The vacuum motor powers the suction, allowing the waste material to be picked up through Kirby's arm.

D Synthetic gas (Syngas) Chamber

This chamber collects syngas - a by-product of gasification. Syngas is mainly composed of carbon monoxide and hydrogen, which is internally combusted to supplement Kirby's battery power supply. In this way, the waste that Kirby picks up helps to sustain his operation.

E Dehydration Chamber

This chamber uses heat and air flow to reduce the water content of the waste, preparing it for cleaner gasification. The fans in the chamber blow out moisture, and channel controlled bursts of steam towards the gasification chamber. Excess heat is removed through vents placed at Kirby's base. Dehydration also reduces the weight of the waste.

F Structured Laser Beam

CERN's Structured Laser Beam is a compact, high precision, robust, non-diffractive beam. In Kirby, these laser beams are directed at waste materials to shred them into small, even pieces that can easily be processed in the dehydration chamber.

G Near-Infrared Spectrometer

The Near-Infrared Spectrometer works by detecting and measuring the interaction of near-infrared light with materials. Spectrometers are used for material identification, as every material has a distinct, recognisable property. Kirby uses this to scan, recognise and sort waste that he vacuums in, separating recyclable materials like glass and metal from other waste.

H Carbon Black Chamber

Carbon black is another by-product of syngas. Since syngas does not emit carbon dioxide, it leaves carbon black behind as a solid residue that cannot be burnt. Carbon black is periodically removed from Kirby to be processed into ink for community centres such as libraries and post offices.

I Gasification Chamber

The gasification chamber is made using a metal matrix composite, one of CERN's Thermal Management Materials, which has high thermal conductivity, excellent thermal shock resistance, and low rates of thermal expansion. This is suitable for the heating of waste at high temperatures for gasification, which is achieved through the application of heat, pressure, and steam.
This system uses microwave-assisted pyrolysis, and works like a conventional microwave oven used to heat our food.

J Recyclable Material Collection Chamber

Materials that are unsuitable for gasification are separated from the waste stream using the Near-Infrared Spectrometer. These include recyclable materials such as glass and metal, which are collected in this chamber. When this is full, Kirby deposits these materials in public recycling bins.

K Motor

Kirby moves from one place to another on omniwheels powered by motor. The motor is able to switch power sources between Kirby's battery and syngas combustion.

L Ventilation Fans

The fans at Kirby's base help to circulate the air from within, since Kirby operates a number of thermal processes. They act like exhausts that are connected to the vents near them.

M Soft Robotics Arm

Kirby's extendable arm is made with compliant materials, allowing flexibility to reach debris in curb corners and under vehicles. As the material is soft, it does not damage parked vehicles.

Figure 20: Kirby's extendable soft robotics arm can reach around obstacles without damaging them

Value Proposition

With Kirby rolling out, the majority of tyre dust particles that settle on the road can be collected, thus preventing them from entering the wider environment. Kirby will also pick up and remove other pollutants, such as microplastics like city dust and road markings, as well as litter, heavy metals, and other urban pollutants. This has the added benefit of reducing the likelihood of flooding caused by the accumulation of debris blocking stormwater drains.

From an ecological perspective, reducing the number of pollutants in the environment will reduce our negative impact on living organisms (Pereira et al. 2015). From a human perspective, less contaminants entering our food and water will lead to positive health impacts as well as cleaner environments for enjoyment and recreation.

Kirby also facilitates material recovery and resource maximisation. He can recover resources that may otherwise have been wasted as he can convert waste to energy to supplement his power supply and separate recyclable materials to be processed for reuse. Kirby also generates carbon black as one of his by-products, which he deposits at community centres such as libraries and post offices to be converted into ink.

Kirby's link to the Bureau of Meteorology allows him to work efficiently as he can prioritise areas that prevent the maximum amount of tyre dust entering water sources. He works in tandem with other street sweeping technologies that focus on the centre of the road and with Dustin, that collects airborne tyre dust. Together, they are able to address pollutants from the entire segment of the road. This greatly reduces the need to remove pollutants from contaminated water, an often more difficult and expensive task (Schilling 2005, p. 11), so that stormwater recycling for domestic use can be carried out more efficiently and effectively.

Kirby is also cost effective as he is able to supplement his power supply with the waste he collects. As he runs autonomously, multiple units can be remotely controlled and monitored from a central source, freeing up human resource.

Additionally, he provides weather-related information to pedestrians. By making metrics such as the air quality index and the amount of tyre dust collected visible, Melbournians can become more conscious of their impacts on the wider environment.

Stakeholder Map and Implementation Plan

Figure 21: Stakeholder map of parties relevant for Kirby's development and adoption

Kirby can be produced by a private company, possibly one that is already engaged in commercial sweeping and cleaning services. As stormwater recycling shifts the emphasis of street cleaning from aesthetics and safety to also encompass ecological and human health, better strategies to prevent as much pollutants as possible from entering stormwater need to be developed. This company can be contracted by the City of Melbourne to provide curbside cleaning services, much like street sweeping services today. Alternately, the City of Melbourne could purchase a fleet of Kirbys to be self-operated.

Kirby's maintenance can be handled by technicians employed either by the contracted company or by City of Melbourne. He can be programmed to navigate to waste management facilities such as City of Melbourne's garbage compactors and recycling hubs located across the city when maintenance is required (City of Melbourne 2019).

Kirby's development can be funded through private equity, and supplemented by grants such as the Litter Innovation Fund offered by Sustainability Victoria that supports innovative approaches to "prevent and reduce the impact of litter and illegal dumping", including plastic pollution and marine debris (Sustainability Victoria 2019a). Melbourne Water could also be incentivised to support Kirby's development, as this would be more cost effective than managing water treatment downstream. A partnership between cleaning technology engineers and those from the waste-to-energy industry can facilitate the necessary improvements in the gasification technology contained within Kirby, as current gasification technologies are not sufficiently efficient.

The Bureau of Meteorology can be engaged to provide weather-related information that helps Kirby to target areas before rainfall. This will also help with their own publicity, as they will have a visible presence in the form of a 'spokesperson' through Kirby.

City of Melbourne can demonstrate Kirby prior to launching him through events such as Melbourne Knowledge Week or at automobile industry conventions. Not only will this raise awareness of the issue of tyre dust and the need to have a strategy combatting it, but also address queries and allay fears that vehicle owners and pedestrians may have regarding the presence of an autonomous robot on the streets and near their vehicles.

Stormwater recycling reveals the high cost of water treatment due to the contaminants from urban run-off. This drives the development of Kirby, an automated curbside cleaning robot that targets tyre dust and road debris before it can reach water sources. With evidence that Kirby reduces levels of stormwater contamination, multiple units are set for rollout across inner city Melbourne in 2030.

Future Steps

We foresee that Scanley can have a continuous impact on people. Due to advancements in science and technology, scientists and marine biologists are continuing to find more evidence of how microplastics affect the ecosystem.

As scanning technology becomes cheaper and more accessible, versions of Scanley could be introduced in science exhibits such as Scienceworks, and subsequently into school science laboratories.

We imagine that beyond 2022, Scanley has scope to be developed into an app for personal devices that can detect microplastic content in food, water, and possibly even microorganisms. This way, people can have a handheld Scanley to detect and avoid or remove unseen plastics or even toxins.

After proposing Dustin in 2025, we believe the technology has more scope to grow. Not only can Dustin be installed on electric fleets such as buses, taxis, and trams but also below the undercarriage of private electric vehicles. Vehicle manufacturers can sell cars with Dustin incorporated as part of the design. With Australia preparing for the rollout of electric bus fleets across the country and the global number of electric public buses set to grow to 1.2 million by 2025 (Cranenburgh 2018), we envision Dustin to be widespread in the coming future - catching most airborne particles and allowing people to breathe cleaner air.

Scientists are currently working on harnessing energy through static electricity (Montalbano 2019). As this technology advances, it could be adapted to be incorporated into Dustin, such that the static electricity used to capture tyre dust could also help to charge the vehicle or power itself. If this is possible, the cost efficiency could result in Dustin being applied to a variety of situations, such as for general air pollutant cleaning in the city.

After Kirby's rollout in 2030, we foresee scope for further expansion to areas beyond inner city Melbourne. The same material identification, sorting mechanism, and gasification technology within Kirby could be incorporated into future bins and material recovery facilities. This could greatly reduce the amount of waste to landfill and incineration. Cheaper and easier material recovery would help to close the loop on the circular economy, as waste becomes more valuable than the cost of processing it. Waste can be converted into power, be recycled for reuse, and generate new by-products such as carbon black.

Kirby could also be modified to become a cleaning implement targeting different sources of microplastics. With advancements in the vacuum and sorting elements, Kirby could be deployed in different environments, such as at beaches and riverfronts, where clean-up activities are currently conducted by hand. Kirby could detect and sort out plastic and man-made debris from organic materials such as sand, twigs and dirt, removing the former and leaving a clean environment behind. Different iterations could also see a version of Kirby that can be used for clean-ups during environmental incidents such as oil spills, or to be deployed as a landfill mining robot, helping to recover precious resources

Conclusion

With Scanley, Dustin, and Kirby rolling out, we can combat the problem of tyre dust in our water sources. This would eventually lead to healthier air and water, especially as we move towards recycling stormwater for domestic use. With these three interventions, we can preserve a healthy ecosystem as people are more aware of microplastic pollution and the need to prevent it.

Scanley. Dustin, and Kirby work together to prevent tyre dust from entering the wider environment so food and water does not get contaminated. Our health, as well as that of the environment, is not compromised. With these conditions, the ocean can thrive once more, and the terrifying prediction that there will be more plastic than fish in the sea (by weight) in 2050 (World Economic Forum, Ellen MacArthur Foundation & McKinsey & Company 2016, p. 17), can be averted.

After all, water is our basic right and our most precious resource. Therefore, keeping it clean and healthy is necessary - for ourselves and for future generations.

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