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Secretariat of the Pacific Regional Environment Programme

PacWastePlus
PACIFIC WASTE MANAGEMENT

This initiative is supported by **PacWastePlus**-a 72 month project funded by the European Union (**EU**) and implemented by the Secretariat of the Pacific Regional Environment Programme (**SPREP**) **to sustainably and cost effectively improve regional management of waste and pollution.**

Research Report:
ASSESSMENT OF END-OF-LIFE TYRES IN THE PACIFIC

February 2022

This study aims to provide peer guidance on recycling potential and current best practice for ELT as may be practically implemented by PICs, to meet guidelines currently in place around the world.

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Acknowledgment: SPREP through the PacWastePlus Programme engaged MRA Consulting Group (MRA) to undertake comprehensive research to determine the possible uses or processing options that exist for end-of-life tyres (existing technologies, uses, processes or management activities), assess each use or option for suitability in the Pacific, and highlight the associated benefit(s) and potential issues with its implementation.

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Our vision: A resilient Pacific environment sustaining our livelihoods and natural heritage in harmony with our cultures.

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Glossary

Terminology	Definition
Bitumen crumb rubber asphalt	An asphalt product which uses crumb rubber as a binder, typically for high traffic roads.
Casings	The rigid, inner of a tyre upon which a tread is placed. Typically, tyres good enough for re-tread or resale as seconds are referred to as casings.
Civil engineering	Engineering discipline that deals with the built environment, including works like roads, bridges, canals, dams, and buildings.
Commercial tyres	Tyres used on trucks, buses, vans, or other vehicles used principally for commercial purposes
Crumb rubber	A highly refined rubber product, typically less than 1mm in diameter, made from recycled tyres.
De-beading	Removing the metal bead from the rim of the tyre, required for some downstream processing of to reduce wear on shredder blades
Domestic recycling	Activities that occur to recycle or reprocess waste tyres within Australia.
End-of-life fates	The destination of an EOLT when it reaches the end of its useful life, including recycling, energy recovery and disposal to landfill
End-of-life tyres (ELT)	A tyre that is deemed no longer capable of performing the function for which it was originally made.
Energy recovery	The use of ELT in a thermal process to recover energy for electricity generation or industrial process.
Equivalent passenger units (EPUs)	A standard measure, based on the typical weight of a standard passenger tyre, used to quantify ELT in Australia.
In-use	Tyres that are in demand for the purpose for which they were originally made.
Landfill / unknown	End-of-life fates for ELT that include licensed and unlicensed landfill, illegal dumping, burning, stockpiling or unreported exports.
MRA	MRA Consulting Group, author of this report
OECD	Organisation for Economic Co-operation and Development
Off-the-road (OTR) Tyres	Tyres from mining sites, heavy industry, and other unregistered off-the-road applications.
PNG	Papua New Guinea
Passenger Tyres	Tyres used on a typical passenger car used for private transport purposes
PIC, PICs	Pacific Island Country, Pacific Island Countries and Territories. As covered by the scope of this study, PICs include Fiji, Papua New Guinea, Democratic Republic of Timor-Leste, Samoa, Solomon Islands, Vanuatu, Federated States of Micronesia, Palau, Kiribati, Tonga, Cook Islands, Tuvalu, Nauru, Niue, Republic of Marshall Islands.

Terminology	Definition
Pneumatic Tyres	Tyres that do not contain an inner tube, the inflating air being sealed within the tyre by the tyre rim sealing against the wheel. See also “Tyre”
Pyrolysis	A two-phase treatment which uses thermal decomposition to heat tyre rubber in the absence of oxygen to break it up into its constituent parts, e.g., pyrolysis oil (or bio-oil), synthetic gas (syngas) and char (carbon black and inorganic matter)
Re-treading	The preparation of used tyres for reuse by replacing the outer tread.
Recovery	ELT that are collected and either reused, recycled, or combusted for energy recovery either in Australia or overseas.
Recycling	Process to recovery constituent materials from end-of-life tyres and use those materials to manufacture other products.
Reuse	The use of tyres for the purpose for which they were originally made, including use of re-treaded tyres and second-hand tyres
Rubber granule	A refined rubber product, typically 2mm – 15mm, made from recycled tyres.
Rubber modified sprayed seals	A road surfacing product that uses crumb rubber as a binder, typically on high stress road areas.
Shredding	Process of cutting up waste tyres using bladed shafts in an enclosed vessel, the size of product being determined by number and orientation of blades and/or number of passes (output screening)
SPREP	Secretariat of the Pacific Regional Environment Programme, the Client for this report
TEU	Twenty-foot Equivalent Units (TEU) is a definition of the volume of materials able to be shipped in a standard 20” shipping container.
Tyre	A vulcanised rubber product designed to be fitted to a wheel for use on, or already fitted to, motorised vehicles and non-motorised trailers towed behind motorised vehicles. For this report, a ‘tyre’ includes but is not limited to those for motorcycles, passenger cars, box trailers, caravans, light commercial vehicles, trucks and truck trailers, buses mining and earth moving vehicles, cranes, excavators, graders, farm machinery, forklifts and aircraft.
Tyre Derived Aggregate (TDA)	Shredded tyres prepared to a specification for use as aggregate in civil engineering applications.
Tyre Derived Fuel (TDF)	Shredded tyres prepared to a specified sizing for use in energy recovery or as a fuel in cement manufacture.
Tyre Derived Products (TDPs)	Any product produced from rubber, steel, textiles, or other material recovery from the recycling of ELT.
Tyre Stewardship Australia	The not-for-profit company established to deliver the National Tyre Product Stewardship Scheme.
TEU	Twenty-foot Equivalent Units
WBCSD	World Business Council for Sustainable Development

The PacWastePlus Programme

The Pacific – European Union (EU) Waste Management Programme, PacWastePlus, is a 72-month programme funded by the EU and implemented by the Secretariat of the Pacific Regional Environment Programme (SPREP) to improve regional management of waste and pollution sustainably and cost-effectively.

About PacWastePlus

The impact of waste and pollution is taking its toll on the health of communities, degrading natural ecosystems, threatening food security, impeding resilience to climate change, and adversely impacting social and economic development of countries in the region. The PacWastePlus programme will generate improved economic, social, health, and environmental benefits by enhancing existing activities and building capacity and sustainability into waste management practices for all participating countries.

Countries participating in the PacWastePlus programme are: *Cook Islands, Democratic Republic of Timor-Leste, Federated States of Micronesia, Fiji, Kiribati, Nauru, Niue, Palau, Papua New Guinea, Republic of Marshall Islands, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu*.

KEY OBJECTIVES

Outcomes & Key Result Areas

The overall objective of PacWastePlus is "to generate improved economic, social, health and environmental benefits arising from stronger regional economic integration and the sustainable management of natural resources and the environment".

The specific objective is "to ensure the safe and sustainable management of waste with due regard for the conservation of biodiversity, health and wellbeing of Pacific Island communities and climate change mitigation and adaptation requirements".

Key Result Areas

- **Improved** data collection, information sharing, and education awareness
- **Policy & Regulation** - Policies and regulatory frameworks developed and implemented.
- **Best Practices** - Enhanced private sector engagement and infrastructure development implemented
- **Human Capacity** - Enhanced human capacity

Learn more about the PacWastePlus programme by visiting

https://pacwasteplus.org/

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PacWastePlus
PACIFIC WASTE MANAGEMENT

About the PacWastePlus Regional Bulky Waste Management Project

PacWastePlus is assisting Pacific Island Countries to improve the management of End-Of-Life vehicles and End-of-Life Tyres by providing guidelines and technical notes on safe handling and dismantling and options for in-country management of these items. This regional project will complement the bulky waste management initiative under the ISLANDS Pacific Project and develop:

- Guiding document and a Decision Support Tool to guide participating countries on how to design and implement a national ELV management programme.
- Develop Drafting/Guiding Notes on how to draft national legislation for the management of identified bulky waste
- Establish safe Dismantling Training Manual to be implemented by national governments to ensure both safeties of workers and prevent discharges into the environment.
- Publications and awareness materials

End-of-Life Tyre Management Publication Series

Technical Booklets: End-of-Life Tyre Management Options

Non-Processing Reuse Options
Non- Processing Method for Utilising ELT: End of Life tyres are utilised "as is" with no processing requirement. Detailed information on repurposing ELT without mechanical or Thermal is provided in the PacWastePlus End of Life Tyre Management – Guideline for Non- Processing Booklet.

Mechanical Processing Options
Mechanical Processing where ELTs are mechanically processed using specialised equipment to create outputs of steel, nylon, and various rubber forms. Detailed information on this type of ELT processing is provided in the PacWastePlus End of Life Tyre Management – Guideline for Mechanical Processing Booklet.

Thermal Processing Options
Where ELTs are substituted in place of new raw materials reduces associated environmental and economic costs. Detailed information on this type of ELT processing is provided in the PacWastePlus End of Lite Tyre Management – Guideline for Thermal Processing Booklet.

Research Report
Assessment of End-of-Life Tyres in the Pacific

Factsheets: End-of-Life Tyre Management

Community

Retailers/Suppliers

Introduction

End-of-Life Tyres (ELTs) are a source of either substitute materials or energy, replacing the need to that can replace virgin materials and fossil fuels and help conserve natural resources. The challenge and opportunity for all stakeholders is to create a system where ELT are considered as a resource available for useful and sustainable markets, without creating a financial burden for any single stakeholder.

Pacific island country (PIC) volumes of ELTs are approximately 7,000 tonnes per year (approximately 470,000 tyres[1]). Existing ELT stockpiles throughout the region are unknown due to incomplete record keeping but are estimated (from import/export data) to be around 125,000 tonnes (approximately 8.3 million tyres). Auditing of the current situation is recommended because the conclusions of this study are based on these figures.

Current efforts at reducing ELT stockpiles appear to be sporadic at best, with waste tyre burning still a common occurrence. Awareness raising of the issues of ELTs among the public to encourage the public sector to establish a system to deal with ELT properly would be beneficial.

Any such campaign may require introducing specific Regulations for ELT use and management, along with associated compliance and enforcement policies. Investment may also be required to engage the necessary resources to monitor and enforce these Regulations.

The Waste Hierarchy should be a fundamental principle of any system to manage ELT, where reuse in the current form would be a higher order process compared to incineration / energy recovery.

Specific options available include:

- Civil/Infrastructure projects can use ELT immediately, with the right encouragement a significant amount existing stockpiles could be utilised.
- Baling of ELT at regional ports prior to shipping to market.
- Transport coordination should take advantage of empty containers and the good will of shipping benefactors to establish regular stockpile reducing shipments.
- ELT Shredding to create a product suitable for either Tyre Derived Fuel or further processing (e.g. granulation). Noting, other waste streams can be shredded and baled, so that the infrastructure for Tyre derived aggregate (TDA) may be subsidised by other users of the assets.
- A mobile ELT processing plant (or multiple of these) could be considered as a regional infrastuctural asset to assist with management of ELT.
- Rubber granules or powder would seem to have a limited market at present, but there are several off-take opportunities.
- Pyrolysis opportunities need to be carefully assessed for operations best practices and strict emissions regulation, but may eventually be of use in ELT stockpile reduction.

Circular Economy principles should be emphasised, endorsed, and encouraged by local government as a critical first stage in determining use or processing of ELT. The economy is most useful for incentivising waste management in communities[2].

[1] Assuming the average weight of a tyre is 15kg.
[2] Ferronato & Torretta - Waste Mismanagement in Developing Countries, March 2019

ELT management planning includes:

- preparing for re-use, (i.e., whole tyres). If the general structure of the tyre is ok, then the tyre may be re-treaded for further use on the road. Whole tyres may also be used in alternative applications to road use, where their size and structure can be utilised (e.g., in civil engineering or structural applications).
    - ELT recycling includes shredding, crumbing, and granulating, and forming ELT into powdered rubber. Some of this recycled material can be re-used in tyre manufacture.
    - energy recovery can be an option for repurposing ELT in country due to its calorific value. However, careful planning and design is required to ensure that no harmful substance is released into the atmosphere and any environmental impact is mitigated.
- creating an ELT management system based on economic principles should be a primary target for PIC authorities. Large cities could be the focus due to its commercial sustainability, multi-level approach across the supply chain and large-scale energy recovery are simply not affordable, particularly for the low ELT volumes available in remote locations.

Without a tyre manufacturer in PIC, there is little opportunity for product improvements that would reduce the amount of waste tyres created. There are opportunities to reduce the waste produced, by authorities encouraging and/or providing:

- improved road surfaces so there is less wear and tear on tyres;
- education on extending tyre life by monitoring tyre pressure;
- the practice of re-treading tyres, primarily for commercial use;
- minimum standards for used tyres being imported by PIC; and information on ELT disposal at point of sale, to encourage responsible decision making by consumers.

Ultimately, without legislation and its consistent enforcement, there may be no commercial incentives for improvements in ELT recovery. By providing the message about the ELT situation and what is possible for optimising this resource, loudly and clearly to consumers, distributors, and policy makers.

This research report aims to provide peer guidance on recycling potential and current best practice for ELT as may be practically implemented by PICs, to meet guidelines currently in place around the world. It is expected that this work will lead to a pathway for implementation and eventually definitive action.

Recommended ELT recovery option for Pacific Island countries are:

- Improvements in specific legislation are required in every PIC to identify ELTs as a separate waste stream requiring specific processing and disposal methods to reduce environmental and health risks.
- Civil/Infrastructure projects should utilise ELT in forms and at volumes appropriate for the application. Management of various stockpiles and allocation of ELT arisings by priority is required so that the ELT resource is optimised for all stakeholders. Public/Private Partnerships may be required to assist with infrastructure investment to set up the ELT processing assets.
- Centralised collection and processing options should be investigated across jurisdictions if required, to consolidate stockpiles in volumes that make investing in ELT processing worthwhile. Likely locations for centralised processing based on geographic location, population and vehicle density are Fiji for Southern PICs and Papua New Guinea for Northern PIC. There are good reasons to review neighbouring countries (Australia, New Zealand, Malaysia) as alternative processing hubs, if shipping can be favourably priced using backfilling of containers, for example.
- Utilisation of ELT in future local cement clinker manufacturing operations should be investigated. If ELT could replace 7,000 tonnes of coal each year, then all the ELT produced in PIC each year would be utilised.
- A market analysis in each Country should be undertaken to confirm the conclusions for each of the applications discussed in this report.

Research Methodology and Data Quality

Data and information for this report have been obtained from publicly available online publications and news articles, through industry websites and direct contact with stakeholders and industry experts in Australia and in some PICs who provided anecdotal or other verbal evidence.

The research was undertaken in four parts:

1. Establishing key resources available for the research;
2. Fundamental review of tyre materials, lifecycle and health hazards under potential end-of-life situations including storage practices;
3. Pacific Island Countries ELT situation:
    - volumes of ELT available now and in the near future;
    - current disposal and processing of ELTs; and
    - collection, storage, and transport logistics for ELTs.
4. Collation and analysis of current and emerging methods of ELT processing. Key data identified related to the importation and use of tyres as well as recycling, re-use, export, or disposal of ELTs.

Data Limitations

There is currently limited specific knowledge of the ELT situation in each Pacific country and there is no single source of information on tyres, ELT, or by-product information. In most cases data has been collated from multiple unrelated sources and commonly from information and publications that are unsubstantiated by government authorities.

Most data on tyres are more than five years old and overall, significant gaps existed in basic data on tyre wastes, their storage and processing, including export volumes. Therefore, in many cases assumptions have been made to estimate volumes.

Addressing Data Limitations

Due to the lack of data with regards to the total ELT stockpiles of each country, estimations were made for individual stockpiles. Data from the United Nations International Comtrade database was utilised to estimate the stockpiles, as the database's records include trade data for each country, and the type of tyres that were imported/exported.

Import data for tyres were taken for each country, subtracting the number of tyres that were exported, with data encompassing a 20-year period, beginning in 2000.

It should be noted that the values calculated may deviate from the actual values due to:

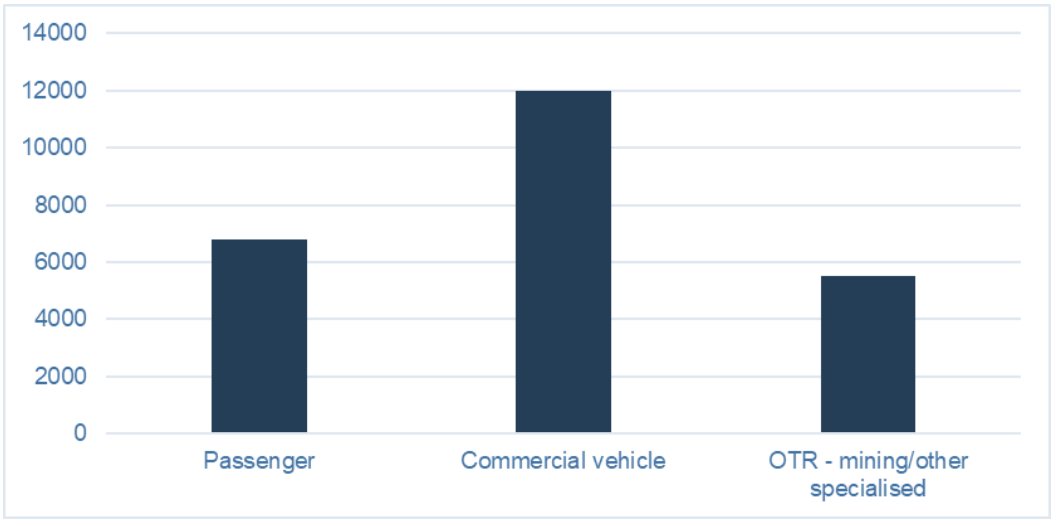
- The practice of tyre burning as a method of disposal is common in PICs; and
- The illegal shipment of used or baled tyres that may have not been accounted for in the Comtrade data.

Tyre Classifications

There are three main application areas for tyres:

- passenger vehicles - Used on a typical passenger car primarily for private transport purposes. These tyres typically weigh around 10kg (ranging from 6 to over 30kg for 4x4 vehicles)
- commercial (truck), Used on trucks, buses, and vans with a chiefly business purpose. The weight of a truck tyre can range from 30kg to as much as 80kg depending on its diameter.
- Off-the-road (OTR) - Used on mining vehicles, roadmaking and farm machinery, go-karts, and aircraft. Typically weigh 200kg on average but varies from 3kg (go-karts) up to 4 tonnes (large mining trucks). Rim size can be from 27 inches to 57 inches

The following graph presents the quantities of tyres by type imported annually into Pacific Island Countries.



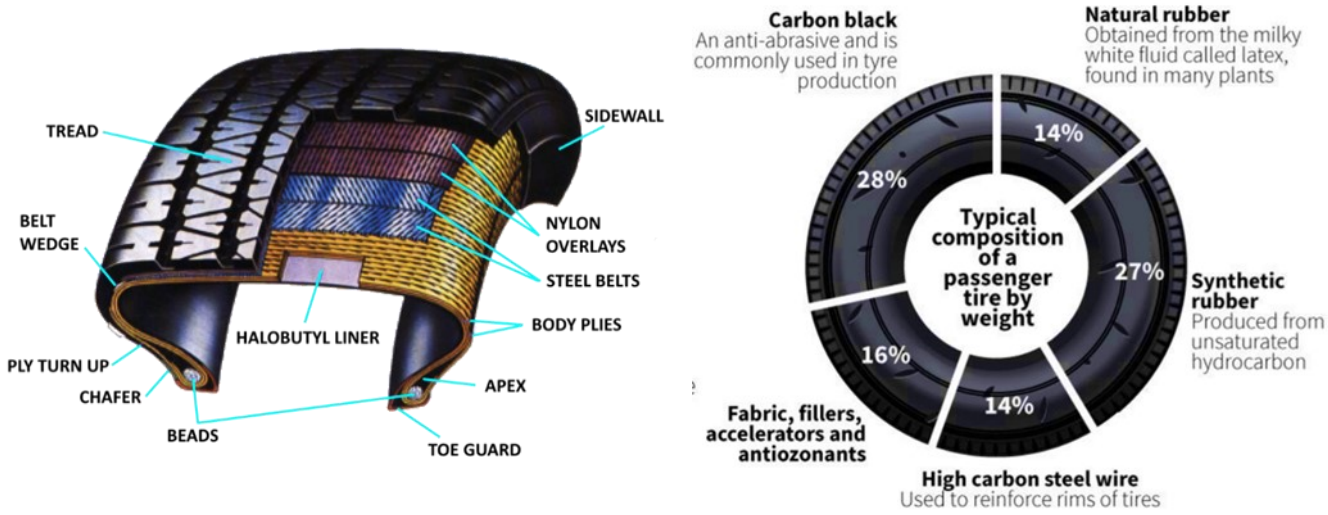
Tyre Components

The composition of tyres differs for each application and manufacturing company. Tyre manufacturing has become an extremely complex mix of brand, market, and technical differentiation so that high level averages must be used to classify tyres by composition.

A basic material composition of tyre material is given below but at a deeper level a typical all-weather tyre has several variances of synthetic rubber, natural rubber, and carbon black. This complex material variety in tyre rubber makes it difficult to reuse waste tyres in making new tyres. Tyre manufacturers develop their own specialised compounds for specific applications in tyre manufacturing; this means no two tyres from different makers are the same.

More than 50 chemicals are used in the construction of tyres. Most of these chemicals are characterised in materials data sheets reported by tyre manufacturers. Typical tyre components of construction are shown in **Figure 1** below:

Figure 1: Tyre construction components



***Source**: Adapted from WBCSD Tyre Industry Project 10-year progress report 2015 and 3M Group "Tyrewise 2.0" Report 2020*

The composition of tyres differs for each application, a basic material composition of tyre material by application is given in **Table 1** below.

Table 1: Tyre material composition by tyre application

Tyre Application	Composition			
	Natural	Synthetic	Steel	Textile
Passenger	28%	52%	15%	5%
Commercial	53%	23%	24%	0%
OTR	70%	30%	0%	0%

Leaching of Chemicals

Tyres will degrade eventually by weathering and are sensitive to sun, temperature, and time causing leaching of toxins. Tests undertaken on ELTs, which contain petroleum products and metals, indicated minimal leaching of iron and manganese into groundwater at levels which were below health concerns. Road pavements have diluted amounts of rubber embedded within the binder matrix so are therefore less prone to leaching concerns.

Biosecurity Risks with Used Tyres

Whole tyres have the capacity to hold water which may allow incubation of mosquito larvae. This presents a biosecurity risk of the spread of mosquitos as non-native species, and the associated risk for disease such as malaria and dengue fever.

In drier regions, dust settles within tyres with the associated risk of transfer of seeds, insects, and other vermin associated with export of baled tyres.

Air Pollution

Tyres when burnt in the open air emit several types of classified pollutants, such as particulates, carbon monoxide (CO), sulfur oxides (Sox), oxides of nitrogen (Nox), and volatile organic compounds (VOCs). They also emit hazardous air pollutants such as polynuclear aromatic hydrocarbons (PAHs), dioxins, furans, hydrogen chloride, benzene, polychlorinated biphenyls (PCBs), arsenic, cadmium, nickel, zinc, mercury, chromium, and vanadium. Tyre fires, apart from intense heat, give off black carbon with CO gas emission.

Health Hazards

Emissions from an open tyre fire can represent significant acute (short-term) and chronic (long-term) health hazards. Depending on the exposure time and concentration, these health effects could include irritation of the skin, eyes, and mucous membranes, respiratory effects, central nervous system depression, and cancer.

Open tyre fire emits s mutagen that causes a change in genetic material in a body cell. It is estimated that open fire emits 16 times more mutagenic than residential wood combustion in a fireplace, and 13,000 times more than coal-fired utility emissions with good combustion efficiency and add-on controls. Mutagens are of concern because the process of genetic damage may cause higher probability of genetic disease in future generations while increasing incidence of somatic cell diseases, including cancer, in the present generation.

ELTs in the Pacific and Timor-Leste

ELT generation is accelerating in most PIC and territories due to little control over the quality of tyres imported. Importation of second-hand tyres tend to have a shorter life and high volume of scrap tyres generated.

End of Life tyres are dumped into the environment leading to stockpiles and risk of fires or mosquito-transmitted diseases. Due to their bulky nature, waste tyres landfilled will quickly consume critical airspace, which is already a major issue for atolls and small islands with limited land space. ELT are not sought after as a resource, therefore PICs and territories that seek to send them abroad for safe recycling or disposal need to pay the corresponding fees. It appears from the limited profile of ELT management, legislation, and standardised practices in PICs that there is low public awareness on the environmental and public health risks related to ELT.

Tyre Stockpile Analysis in Pacific Island Countries and Timor-Leste

Fiji and PNG comprise 80% of the new tyre import market and 78% of all tyre imports in the Pacific. Fiji and PNG also have an estimated 72% of all PIC stockpiles. A large percentage of commercial tyres are imported by Fiji and PNG, and the overall imports by tyre type are represented in the table below.

Table 2: PIC tyre imports, exports, and stockpile estimation (all data in tonnes)

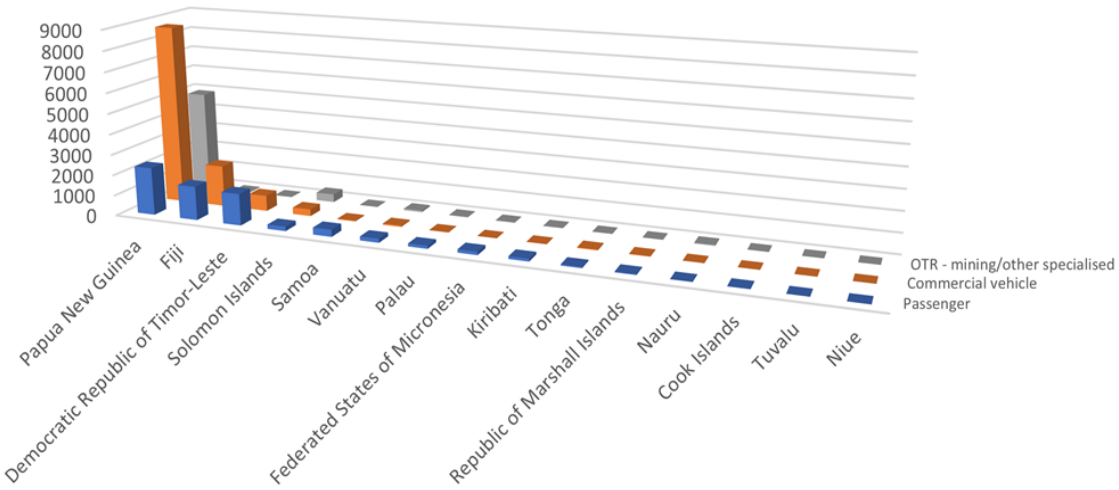
Country	New Tyre Imports (2000-2020)	Used and Re-treaded Tyre Imports (2000-2020)	New Tyre Exports (2000-2020)	Used and Re-treaded Tyres Exports (2000-2020)	ELT Stockpiles
Cook Islands	236	8	0	0	0*
Democratic Republic of Timor-Leste	8,755	1,083	24	333	3,616
Federated States of Micronesia	1,195	1,341	0	0	2,310
Fiji	48,767	8,619	500	59	51,628
Kiribati	741	378	1	0	971
Nauru	n/a	n/a	n/a	n/a	0*
Niue	n/a	n/a	n/a	n/a	0*
Palau	1,142	386	9	0	1,235
Papua New Guinea	47,904	2,446	0.5	1	46,310

Country	New Tyre Imports (2000-2020)	Used and Re-treaded Tyre Imports (2000-2020)	New Tyre Exports (2000-2020)	Used and Re-treaded Tyres Exports (2000-2020)	ELT Stockpiles
Republic of Marshall Islands	n/a	n/a	n/a	n/a	0*
Samoa	5,955	990	5	10	5,921
Solomon Islands	4,563	917	4	3	5,313
Tonga	731	1,051	0.5	0.5	1,634
Tuvalu	20	0	0	0	20
Vanuatu	1,205	80	2	0	665
Total tonnes	**120,473**	**17,299**	**546**	**406.5**	**119,623**

* ***Note*** *that zero stockpile values indicate greater number of tyres in use (based on vehicle registrations) compared to total imports, i.e., data is missing or incomplete for imports.*

The volume of tyre import into 14 pacific countries and Timor-Leste is estimated using data from the United Nations Comtrade database, specifically records of trade data and the type of tyres that were imported/exported. PNG imports most of the OTR in the region. OTR are typically used in mines and farming activities, with a small number of other sources (e.g., aircraft, go-karts, recreational vehicles).

Figure 2: Volume of tyre import into 14 pacific countries and Timor-Leste



Source*: MRA reference data 2021*

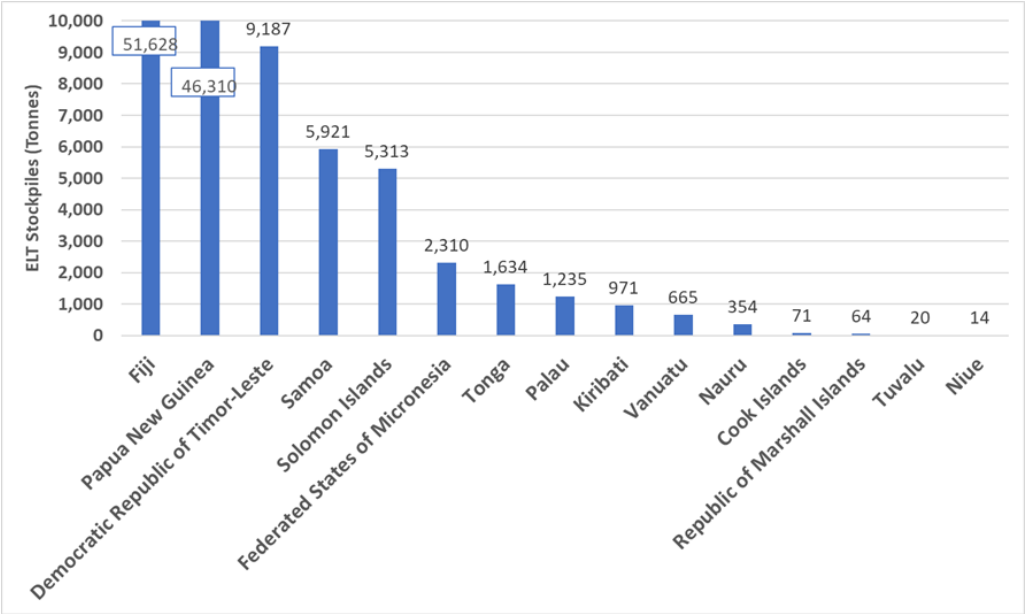
Estimated ELT Stockpiles in the Pacific & Timor-Leste

Stockpiles in the Pacific was determined using data from the United Nations Comtrade database, specifically records of trade data and the type of tyres that were imported/exported. Import data for tyres were analysed for each country, subtracting the tonnes of tyres that were exported to estimate stockpile volume. It should be noted that the values calculated may deviate from the actual values due to:

- The practice of tyre burning as a method of disposal, common in most PIC; and
- The undocumented shipment of used or baled tyres that cannot be captured by Comtrade.

Estimated stockpiles for other Pacific Countries is highlighted in **Figure 3.**

Figure 3: Estimated ELT stockpiles for Pacific Island countries (2000-2020)

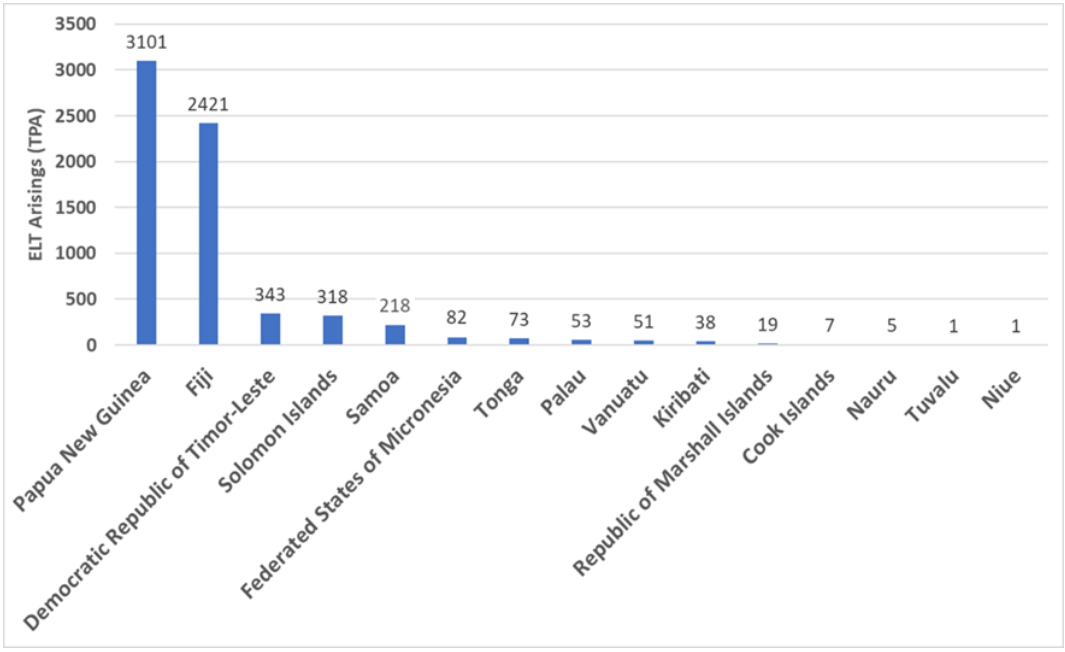


***Source**: MRA reference data 2021*

Used Tyre End-of-Life Arisings

It is estimated that 6,706 tonnes, or 670,600 tyres, reach end of life annually across all PICs (**Figure 4**:**).** This is based on estimated tyre import and stockpile volumes and assuming a lifespan of 3.4 years for a passenger car tyre, 1.5 years for a truck tyre and 1 year for an OTR tyre.

Figure 4: Estimated generation of ELT in Pacific Island countries per year



***Source**: MRA reference data 2021*

Current Disposal and Processing of ELT in the Pacific

Illegal Disposal

It is estimated that 22,000 tonnes of tyres are illegally stockpiled, buried or burnt based on information on unaccounted stockpiles, annually in PICs.

Landfilling

Regulated landfilling involves the collection of waste tyres by a solid waste hauler who is paid to remove ELT from the tyre dealer's property. Most landfills in PIC accept whole ELT but some may charge a tipping fee because tyres are awkward to handle and difficult to compact with regular waste. Because they may retain pockets of air, scrap tyres tend to float or rise to the surface of a closed landfill over time, causing damage to the landfill cover.

Storage

Review of several sources of PIC waste and recovery organisations, tyre businesses and anecdotes in the press, indicates that ELT storage practices in PIC tend to be ad-hoc and unregulated, leading to hazards.

Tyre Re-treading

Re-treading of used tyres is a practice done mostly for extending the life of commercial tyres. Some commercial tyres can be re-treaded two to three times over the life of the tyre. Re-treading a tyre will not eliminate it from contributing to the ELT problem because the re-treaded tyre will eventually wear out, probably in less time than a new tyre. However, re-treading delays the appearance of tyres at the ELT stockpile and thus reduces the overall number of ELT that would have appeared in the lifecycle. The choice to resell or re-tread is generally be made either by the end user or during collection by vehicle maintainers as it is not practical to evaluate and separate tyres for re-treading at the tyre recycling facility.

Because ELT are defined as “end of life” tyres, re-treading is effectively “re-use” and is therefore not considered in this study except in the lifecycle options presented in Figure 10 and as background used tyre volume data. It should be noted that re-treading tyres is recommended by some studies as the most cost-effective method of recycling of tyres.

Shredding

It is understood that small scale shredding operations are underway in PNG, Marshall Islands, and Palau and investigations into shredding processes are ongoing if not already underway for Samoa.

Tyre shredding represents the process used for the majority of ELT recycling processes around the world. Shredded tyres are often exported as TDF (for example, 63% of ELT exports from Australia). TDF has the benefit of reducing dependence on fossil fuels, burning cleaner than coal, achieving a better ranking on the waste hierarchy than disposal, and producing less greenhouse gas emissions than burning of brown coal. There is potential for future PIC use of tyre shred in clinker production in proposed cement kilns in PNG, and as a fuel source for other applications. Civil/infrastructure applications for shredded tyres include:

- Road embankments;
- Subgrade fill in soft soils;
- Landfill (drainage layer, gas capture pipe backfill);
- Void filler (behind retaining wall);
- Drainage media; and
- Vibration damping layers.

Assessment of Current ELT Disposal Method and Existing Waste Management Legislation

The table below highlighted current ELT disposal methods, and legislation addressing ELT for 14 Pacific Island Countries and Timor-Leste. It appears that there are currently no specific legislations addressing ELT management except for occasional references to burning of tyres as relevant to air pollution controls. Samoa is the only country in the region to have an import restriction in place.

Table 3: Disposal method and legislation by country

Country	Industry tyre disposal method	Legislation
Cook Islands	Used tyres are often burnt, dumped, or stored with the burning of tyres being illegal under Cook Islands Public Health Act (2004). Reuse of used tyres on vehicles is also common. Potential "Tyre Deposit" scheme has been proposed	Public Health Act 2004 Part 6 Waste: Article 38 states that Plastic waste and tyres are not to be burnt without authorisation. The Environment Act 2003 governs the responsibilities different agencies have in the management of waste. The Act also establishes the National Environment Service and the Island's Environment Authority who have the power to enforce regulations on illegal dumping and environmental policy education. There are no specifics relating to ELT.
Democratic Republic of Timor-Leste	Tyre waste is stockpiled at the Tibar Rubbish dump or is subject to open burning operations Reports of 2 tyre recycling firms No known method of recycling.	No specific mention of ELT in Legislation The Hygiene and Public Order Decree Law 33/2008 prohibits illegal dumping of waste in public sites with fines between $5-$500. Burning of solid wastes can attract fines of $115.
Federated States of Micronesia	Illegal dumping and burning of waste, including tyres, is common practice. Waste tyres are typically stockpiled in dumpsites that are overcapacity	No specific mention of ELT in Legislation All four of the FSM states possess legislation relating to waste management in their specific region: The Kosrae Island Resource Management Authority administers State Constitution, Article 2 regarding governance of waste management in Kosrae. Chuuk State Littering Act 1991 prohibits the disposal of waste in public and Pohnpei's EPA administers the Solid Waste Regulation 3/30/95 regarding waste disposal fees. The State of Yap, Law No.4-4 (State Public Service Corporation) covers waste collection and restrictions on waste imports
Fiji	Stockpiling in landfills and burning of used tyres in kilns. Waste tyres are also one of the nation's major exports.	Environment Management (waste disposal and recycling) Regulations 2007 - part 5: control of air pollution mentions that tyre burning is an offence without a permit with a fine of FJ$10,000. The Environment Management Act 2005 stipulates that anyone "who knowingly or intentionally or with reckless disregard to human health, safety or the environment, causes pollution incident that results in harm to human health or safety, or severe damage to the environment commits an offence and is liable on conviction to a fine not exceeding FJ$1,000,000 or to life imprisonment or both". This penalty is five times higher for a business or a corporate.

Country	Industry tyre disposal method	Legislation
Kiribati	Used tyres are currently stockpiled	No specific mention of ELT in Legislation The Environment (General) Regulations 2017 stipulates the fees involved in waste disposal and the seizure of environmentally harmful equipment. The Environment (Amendment) Act 2007 s 20 'Duty to clean-up environment' provides that a person who causes or allows the discharge of any waste or other substance in contravention of the Act must take any appropriate actions to remove the waste or other substance and remedy, mitigate and contain any harm to the environment. A person who fails to comply with the subsection commits an offence (max. fine AU$100,000 or 5 years imprisonment).
Nauru	Tyre waste is currently stockpiled on the island at the only landfill, operated by Nauru Rehabilitation Corporation.	No specific mention of ELT in Legislation The Litter Prohibition Act 1983 empowers local district constables to fine individuals for littering offences. The Environment Management Bill 2006 prohibits and regulates pollution in the environment as well as administering the management of landfill sites. More current legislation is under review.
Niue	No known disposal activities or tyre collection fee. Tyres typically burned or stockpiled (assumption)	No specific mention of ELT in Legislation The Environment Act 2015 regulates activities, both state and private, that would affect Niue's environment.
Palau	Shredding (Through the use of a tyre shredding facility at the M-Dock Landfill) and stockpiling of the tyre shreds	Air Pollution Control Regulations prohibit open burning of wastes and specifies tyres in this regard. The National Code Title 24: Environmental Protection establishes the Environmental Quality Protection Board and regulates waste disposal in Palau and the enforcement against illegal dumping.
Papua New Guinea	Ok Tedi - Shredding and granulation of OTR tyres only (Eldan Recycling) – granulate for unknown further use by one customer.	No specific mention of ELT in Legislation The Environment Act 2000 outlines the primary legislation for environmental protection in PNG. However, legislation specific to waste management is lacking along with the enforcement of fines related to littering offences.
Republic of Marshall Islands	Illegal dumping and stockpiling. Tyres are currently shredded on Majuro Atoll. No fees for households, $5-10 for waste for businesses depending on size and time of arrival to landfill	No specific mention of ELT in Legislation The Solid Waste Regulations 1989 provides input into the management of solid wastes and their disposal as well as the enforcement of standards for recycling facilities. It also establishes the enforcement against illegal dumping.
Samoa	Stockpiling with tyre shredding operations currently being implemented.	In 2015, Cabinet approved the prohibition of ELT imports due to public health concerns. Such concerns include the potential effects of these materials in the waste stream. The *Waste Management Act 2010* regulates the management of all waste types as well as establishing community by-laws and initiatives.
Solomon Islands	Tyre waste is stockpiled in landfills or is burnt in illegal burning operations, the latter of which is common in rural areas due to the lack of sufficient waste service collections. There is a partnership between the nation and NZ-based Nufuels in developing a pyrolysis-	No specific mention of ELT in Legislation The Environment Health Act 1980 establishes the responsibilities the Ministry of Health and Medical Sciences have in providing expert advice relating to the development

Country	Industry tyre disposal method	Legislation
	based pilot plant in converting waste tyres to liquid fuel.	and implementation of environmental health policies relating to waste management. The Honiara City Act 1999 assigns the responsibilities of waste collection and disposal to the Honiara City Council. The Honiara Litter By-Law 1994 prohibits littering in public spaces.
Tonga	Tyres are stockpiled and burnt illegally.	No specific mention of ELT in Legislation The Waste Management Act 2005 relates to the management, collection, and disposal of wastes in Tonga, including the definition of specific waste offences including littering. The Public Health Act 2008 relates to the disposal of toxic, flammable, and explosive wastes.
Tuvalu	Tyre waste is noted to be exported to other countries	No specific mention of ELT in Legislation The Waste Operations and Service Act 2009 relates to the responsibilities undertaken by government agencies regarding waste management. This includes waste collection, disposal and management as well as enforcing the ban on littering and waste incineration.
Vanuatu	Tyre waste is stockpiled in the Bouffa landfill in the Port Vila Municipality. Tyre burning is common in areas not serviced by the Municipality.	No specific mention of ELT in Legislation The Waste Management Act 2014 encourages the provision of effective waste services and operations as well as establishing the different waste responsibilities for government agencies. These responsibilities are shared between the Department of Environmental Protection and Conservation as well as with municipal and local councils and the Ministry of Health and Biosecurity Vanuatu.

Institutions within Pacific Island Countries tasked with regulating waste in general may have limited capacity to effectively address ELT management due to:

- Insufficient and unsustainable financial resources;
- Insufficient staffing;
- Limited appropriately trained staff;
- Limited infrastructure;
- Requirement to service large, widely dispersed areas and multiple islands; and
- Inadequate surveillance, monitoring and enforcement.

Area for Improvement of ELT Management in the Pacific

Summary of Improvements Required

- Environmental legislative instruments (Acts, Regulations, Guidelines etc.) should specifically refer to waste tyres or ELTs as requiring a separate waste treatment (separate from landfill or incineration). As a minimum the proper storage and landfill treatment of waste tyres should be noted.
- Any import of tyres, new or used, should include a provision for ELT utilisation, whether by application of an import fee per tyre to cover costs of processing, or by import regulation to limit the total ELT generation rate to that which can be managed by present treatment or disposal methods.
- Import regulation of used tyres or ELTs should prohibit import of substandard (waste) tyres ostensibly for use on vehicles.
- Open air burning of waste tyres should be specifically prohibited in all legislative Acts or Regulations dealing with pollution and waste.
- Awareness of the growing problem with ELTs, the volume, stockpile, and environmental issues as well as the opportunity for resource utilisation should be addressed in the form of education and legislation.
- Annual audits of waste tyre stockpiles should be conducted by each municipality to monitor and control the number of stockpiles and tyre storage methods.

Regulatory Requirement

International experience has shown that to improve ELT management, it is necessary to expand legislation to add specific ELT clauses in waste and environment legislation to regulate the recovery and disposal of ELT. The World Business Council states:

Governmental support is crucial in providing the legal framework in which the ELT markets can be developed. Moreover, as they can affect public health, allow the development of new industries, and create employment, there is an even greater expectation for local governments to drive ELT recovery markets and control illegal ELT generation and treatment. Setting the status of ELT is one of the first steps taken by local regulations, defining it as product or a form of waste and determining potential for import or export and the logistics of land transported ELT since, when considered waste, some countries require transportation companies to have a specific permit (e.g., Italy).

Whilst policy and regulation related to ELT is generally the concern of each PIC, the implementation of Product Stewardship arrangements in each country is a means of addressing specific ELT challenges. Product stewardship is an approach which recognises that all participants in the product chain have a responsibility to ensure that the product can be appropriately managed at end of life. Through appropriate legislation and cooperation with private sector, it should be possible to record the numbers of tyres replaced on vehicles and therefore obtain more accurate data on ELT generation.

Tyre Disposal Fees

Implementation of incentives for tyre collection and proper disposal or recycling would assist to fund the necessary management activities for ELT. To justify the cost of collection and recycling, tyre companies may charge a fee to consumers to take away ELT.

There are reports that retailers charge the fee but stockpile or export ELT instead of recycling them. This is something that PIC should be aware of and be prepared to address through legislation and enforcement.

In Australia the fee is up to $5 per tyre, although recyclers will receive something in the order of $1.80-$2.50 per passenger tyre in metropolitan areas.

There are examples found of PIC waste companies charging a separate fee for tyre disposal (e.g., in Guam), however fees are typically mixed in with other waste types so cannot account for tyres separately.

It is expected that utilising such a disposal fee within PIC to fund actual costs of processing may direct some whole tyres away from landfill or illegal dumping toward the alternative of turning ELT into useful products such as TDF and rubber crumb.

In New Zealand until at least 2019/20 most tyre retailers were charging an "environmental fee" to customers that ranges from NZ$2.70 to NZ$17.19, depending on the size of the tyre.

Best Practice ELT Storage

In the absence of specific ELT legislations and infrastructures in Pacific Islands countries, this report identifies meaningful management for the storage of ELTs in the short-term to support pacific countries with existing stockpiles.

For outdoor storage:

- A stack should not exceed 6m in width and 20m in length;
- The edges of the pile should be at least 15 m from the perimeter fence and this area should be free of debris or vegetation;
- Interior fire breaks should be at least 18m wide;
- The area extending 60m from the outside perimeter of the piles should be devoid of any vegetation;
- Inhabited buildings, parked vehicles, etc. should also be at least 60m from tyre piles;
- The site should be flat, with a concrete or hard clay surface and should be designed to capture and contain water run-off;
- Scrap tyre storage should not be on wetlands, floodplains, ravines, canyons, or on any steeply-graded surfaces;
- Any open-air burning should be at least 300m from the tyre pile;
- Heat generating devices (e.g., welders) should not be operated within 60m of tyre piles; and
- Lightning rods should be installed, but away from the tyre piles.

By utilising these arrangements, in the event of a fire, firefighting operations can be assisted by preventing concentrated fires from forming within stacks. Long and thin piles, for both indoors and outdoors, are recommended to prevent fires from spreading between stacks.

For indoor storage:

Tyre stacks should be stored at a maximum of 3.7m high with a maximum area of 30m^2.

- Stacks are to remain at a minimum of 2m distance from each other as well as from containing building structures;
- Any stockpile of tyres of 20 tonnes or more should be accompanied by a sprinkler system;
- In storage areas where there are no sprinkler systems present, 3m is the recommended inter-stack distance for best practice; and
- There should be a minimum of 1 metre distance between stacks and walls and roofs.

It is also recommended that tyres are stacked using the following methods to minimise the intensity of a fire:

Barrel Stacking: This includes storing tyres vertically in a stack with the intent of preventing fires from spreading to different stacks, due to the 'whirlpool'

Laced Stacking: Whereby the tyres are stacked in an overlapping fashion, forming a 'lace' pattern that maximises use of storage area whilst at the same time reducing the risk of tyres rolling off the stack.

While ELT stacking can be a useful temporary solution for stockpiles, it is recommended that tyres are shredded at the earliest opportunity as shredded tyres are storage space efficient as well as more resistant to burning than stacking.

Challenges and Solutions for Implementation

Table 4 identifies and discusses key challenges for ELT management in the Pacific and Timor-Leste and further explores possible management options.

Table 4 Challenges to managing ELT in the Pacific with possible management options

Challenges	Management Options
Absence of in-country recycling infrastructure Two major technical obstacles to effective and efficient ELT recycling in PICTs are the lack of in-country recycling and re-processing facilities, and the high cost of shipping ELTs elsewhere due to the geographical isolation of many of the PICTs. The small populations of most PICs are another significant factor in that conventional recycling and processing operations are only commercially viable with a much larger base source of materials from a significantly higher population.	**Management Option 1**: This report aims to introduce PICs to the potential solutions for several scenarios of tyre waste volume and accessibility. It is not always possible or necessary to build ELT processing infrastructure, when other available or cost-neutral mechanisms may be more suitable for the situation. A tyre shredder that can process 4 tonnes of ELT per hour will process a tyre stockpile of 1000 tonnes in 6 weeks – but this machine will break down if only occasionally used and maintained. A minimum of 4,000 tonnes per year (500,000 tyres) is notionally required for any processing solution to be viable. The recommended system for low volume ELT generating countries is for ELTs to be baled for high-density storage at a central collection point, then picked up regularly by ship for transfer to a central stockpile location for combining into sufficient volume for campaign processing. Larger population centres should be the focus for developing this processing infrastructure, because a commercially sustainable, multi-level approach across the supply chain and large-scale energy recovery are simply not affordable, particularly for the low ELT volumes available at the geographically dispersed ELT sources. **Management Option 2**: The synergies of general waste processing, rather than small volume, niche materials streams such as ELTs, cannot be ignored. It is more viable to obtain value from multiple end-product markets through combined processing of the larger volume waste streams. To this end, any waste processing infrastructure considered for general waste (MSW, e-wastes, composts etc) should also consider ELT processing requirements, and vice-versa. Noting that contamination of ELTs with other wastes may make processing more difficult and less efficient. **Management Option 3:** A roving mobile processing plant could be used to remove small volumes of ELTs from communities. This solution would alleviate the need for expensive, complex machinery to be in situ at each collection point. The mobile equipment could be provided by commercial enterprise, along with an appropriately sized barge or vessel to collect and store the stockpile of TDP along the way. The destination of the vessel would be close to the TDP end use site. **Management Option 4**: All ELTs are collected and processed to whatever level required for transport to PNG's proposed cement plant near Port Moresby, to substitute for thermal coal use. This solution is lowest on the waste hierarchy due to potential emissions and minimal energy gains. Further understanding is required of the opportunity for processing and in what form the TDF is required. Noting that some cement plants use tyres whole while others require TDF in shredded form.

Challenges	Management Options
Insufficient Funding There are insufficient funds allocated generally to the waste management sector and specifically to ELT recycling. It follows that lack of funds severely limits the development of necessary infrastructure and resources for efficient recycling of ELTs and waste in general.	Provide incentives for the commercial sector to consider investing in the infrastructure required to develop a materials recovery resource from ELTs.
Absence of a regional recycling mechanism There is an absence of a multi-regional orientated or coordinated recycling mechanism, apart from the "pro bono" Moana Taka agreement (which is chiefly aimed at low value, non-commercial waste streams).	PICs have successfully exported waste material to recycling companies in Asia, Australia, and New Zealand. The solution is to set up a value stream (the market) with several product customers and promote the cross-border utilisation of ELTs within the PIC communities. A coordinated stockpile management system could be established to monitor and advertise volumes of ELT available and in what form, so that registered customers can reserve volumes for pick-up when required.
Limited awareness on ELT The lack of an existing market for recyclables can be attributable to a lack of waste education and promotion of circular economy principles. Only a few PICs have established strategies in the public sector to encourage and promote waste minimisation. There is often a perception that ELTs are simply waste products and of little or no value, despite their obvious performance benefits as Tyre Derived Products in many instances.	Local community and country policies should be drafted to encourage the growth of reuse and recycle markets for ELTs. These may include specific investments in sustainable infrastructure like rubber-modified asphalt and stormwater infiltration galleries, changes in transportation specifications to allow the use of rubber modified asphalt in roads, and consideration of ELTs in drafting of climate policies.

Options for Utilisation of ELT

While the PacWastePlus funded research on Option of ELT utilisation does not address market fundamentals, it proposes viable methods of treatment for potential markets. There are various ELT markets existing in different countries that have developed according to local cultural, political, and industrial contexts that can be accessed by PIC.

ELT management is continually evolving, present systems have been adapted over time as learning about ELT management has increased. The value destruction, or opportunity cost of environmental and health effects must be weighed against the financial costs of implementing the ELT system.

The PacWastePlus research has led to the creation of the following resources:

Technical Booklets: End-of-Life Tyre Management Options

Non-Processing Reuse Options
Non- Processing Method for Utilising ELT: End of Life tyres are utilised "as is" with no processing requirement. Detailed information on repurposing ELT without mechanical or Thermal is provided in the PacWastePlus End of Life Tyre Management – Guideline for Non- Processing Booklet.

Mechanical Processing Options
Mechanical Processing where ELTs are mechanically processed using specialised equipment to create outputs of steel, nylon, and various rubber forms. Detailed information on this type of ELT processing is provided in the PacWastePlus End of Life Tyre Management – Guideline for Mechanical Processing Booklet.

Thermal Processing Options
Where ELTs are substituted in place of new raw materials reduces associated environmental and economic costs. Detailed information on this type of ELT processing is provided in the PacWastePlus End of Lite Tyre Management – Guideline for Thermal Processing Booklet.

Research Report
Assessment of End-of-Life Tyres in the Pacific

Factsheets: End-of-Life Tyre Management

Community

Retailers/Suppliers

The challenge and opportunity for all stakeholders, is to create a system where ELTs are considered as a resource available for useful and sustainable markets, without creating a financial burden for any single stakeholder.

For an ELT recovery system to operate sustainably, it should include:

- an environmentally sound, economically viable and self-sustaining end-use market.
- a coordinated approach to address the collection, transport, storage, and local processing of ELT for the chosen market.

Confirmation of import/export tyre volumes, together with mapping and assessment of historical ELT stockpiles, to ensure the Option selected will effectively manage the volumes required.

An approximate market and processing analysis is presented in the **Table 5**, for consideration.

Table 5: PIC available ELT volumes and processing options

Tyres p.a.	Tonnes p.a.	Tyres per Day	Example PIC	ELT Processing
500	5	3.3	Niue, Tuvalu	1. Confirm and consolidate ELT stockpiles 2. Set up monitoring network for civil/infrastructure use of stockpiled ELT 3. Combine remaining stockpiles with ELT arisings for processing at central location. Bale if possible 4. If shredding, process to TDF specification
1,000	10	5	Kiribati, Cook Islands FSM	
5,000	50	25	Solomon Islands Vanuatu Timor-Leste	
10,000	100	50	Samoa, Tonga, Nauru	
50,000	500	250	Marshall Islands	1. Civil/Infrastructure project use of ELT 2. Centralised Shredding for market as TDF 3. Maintain consistent feedstock generation for PNG cement plant
100,000	1,000	500	Palau	
500,000	5,000	2,500	PNG	1. Consider setting up central TDF handling facility 2. Process in PNG cement plant in future 3. Consider Granulation if market is secure

Option Analysis

Option 1

Centralised Shredding of ELT at one main facility for each PIC may address the immediate need, but unless the tyre shred can be utilised locally (e.g., in Construction/Infrastructure projects), the final product can only be shipped to other countries.

Shredding can reduce tyre volume by up to 75%, also reducing transportation costs by 30-60% simply because fewer trips are required, and maximum hauling weights may be achieved more easily. Setting up a Central shredding facility e.g., in PNG near the proposed cement plant may alleviate costs for the outlying countries shipping whole tyres to the shredder. However, if finances allow, shredding is better undertaken at the remote islands to reduce shipping costs and storage issues.

Option 2

Another option is to set up a mobile shredding facility that can be barged around to each PIC to shred tyres. The vessel would travel around to each country as required, reducing ELT volume to an appropriate level before continuing to the next country. This solution would alleviate the need for expensive, complex machinery to be in situ at each country.

Option 3

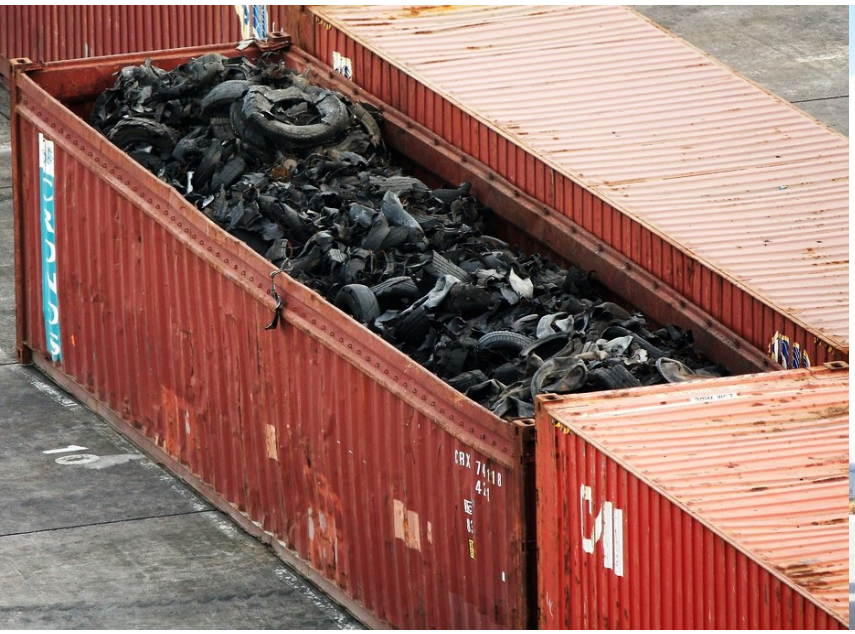
Other localised markets such as construction projects may established more sustainable value to individual PICs. Public Private Partnership should be encouraged to review and contribute to the business case development for ELT Management. Subsidised ELT transportation where backfilling of cargo vessels with containerised waste may make commercial sense. The best example of this is the Moana Taka agreement, where shredded tyres can be shipped for processing.

Table 6 indicates potential for backfilling of empty containers leaving major ports in the PIC islands. Indicative costs for transport of tyres in a 20' container (Twenty-foot Equivalent Units -TEU) is also provided, as a comparison for cost savings for any pro-bono agreement.

Table 6: Container backfill opportunities and costs by PIC ports

Country	Empty Containers Leaving Port	Typical Shipping Cost and Destination
Cook Islands	1,900 Port of Avatiu	US$3,150 per TEU to New Zealand
Democratic Republic of Timor-Leste	Unknown	
Federated States of Micronesia	2,800 Port of Pohnpei 1,900 Port of Yap	US$1,100 per TEU to Guam
Fiji	16,066 Port of Suva	US$950 for intra-island TEU transport

Country	Empty Containers Leaving Port	Typical Shipping Cost and Destination
Kiribati	2,300 Port of Tarawa	US$2,500 to $3,300 per TEU to Fiji
Nauru	Unknown	
Niue	Unknown	
Palau	2,600 Koror Port	US$3,860 per TEU to North Asia Palau Shipping Co. also services Marshall Islands and Micronesia.
Papua New Guinea	19,000 Port Moresby 43,550 Port of Lae	US$2,200 per TEU to Australia
Republic of Marshall Islands	3,931 Port of Majuro	US$2,500 to $4,000 per TEU to Fiji
Samoa	11,300 Port of Apia	US$2,500 to $4,400 per TEU to Fiji
Solomon Islands	11,200 Port of Honiara	US$2,900 to $3,300 per TEU to Fiji (3 other international ports, Noro, Viru, Yandina)
Tonga	7,000 Port of Nuku'alofa	US$2,500 to $4,400 per TEU to Fiji
Tuvalu	900 Port of Funafuti	US$3,200 per TEU to Fiji
Vanuatu	2,500 Port of Santo	US$2,500 to $3,200 per TEU to Fiji



Overview of Environmental Impacts of Options

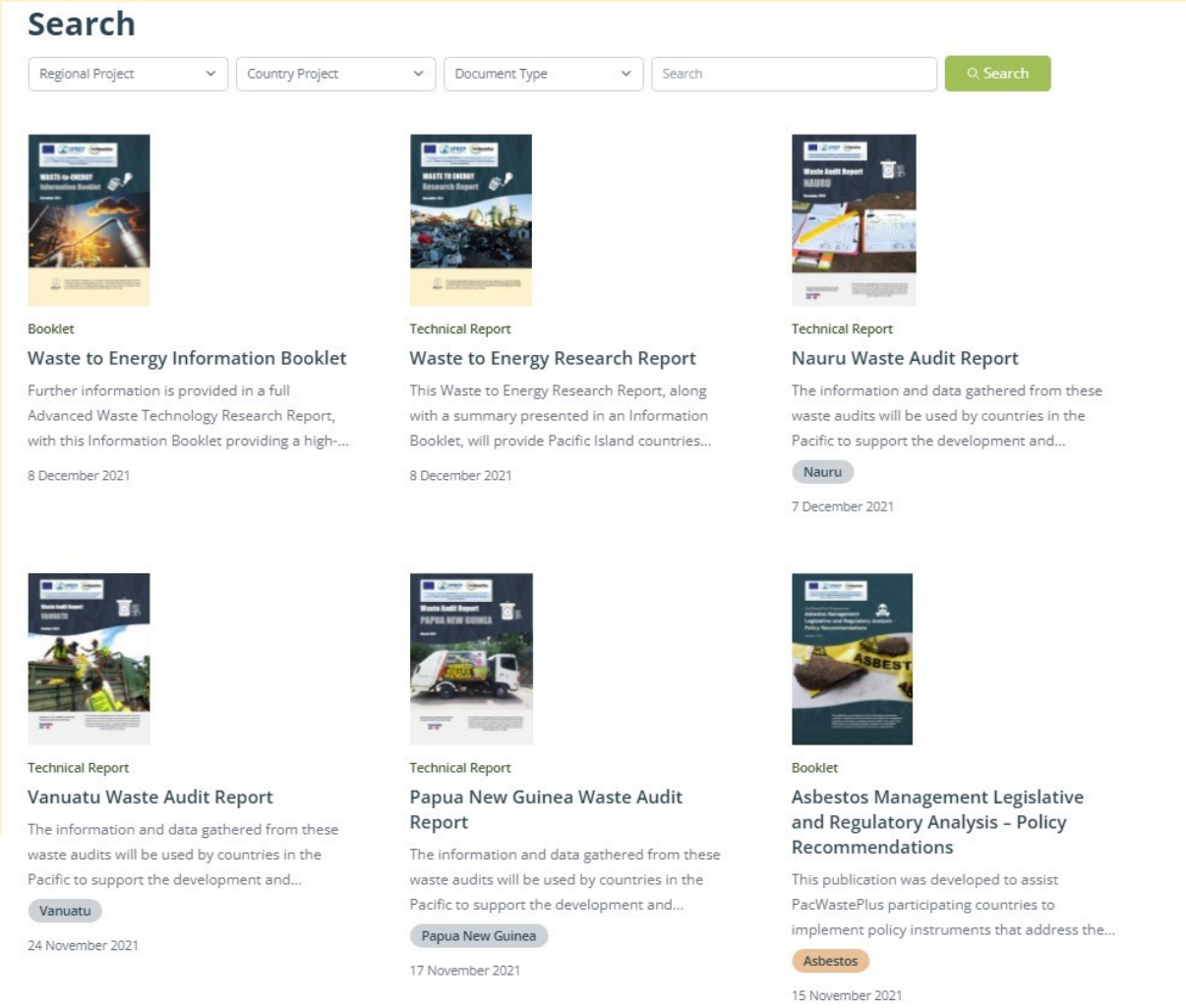
The environmental impacts of each ELT processing options are discussed more in the supplementary guidelines on discussed in the previous section, however an overview of three common air emissions is presented in **Table 7** to indicate a relative index of pollutants. Emissions to ground can be considered as negligible compared to the air emissions.

Thermal processing clearly emits at least as much polluting gases as burning of tyres in the open. Producing rubber modified asphalt is effectively a thermal process, emitting a massive amount of carbon monoxide. This information is presented for decision making as to preferred processes to implement in local jurisdictions where tyre burning may be banned, but other options may be just as bad.

Table 7: Emitted air pollutants for each ELT process

Process	SOx (ppm)	NOx (ppm)	CO (ppm)	Total (ppm)
ELT Granulation	0	0	0	0
Civil/Infrastructure Applications	0	0	0	0
Landfilling	0	0	0	0
Rubber Modified Asphalt	76.7	124.4	259.5	460.6
Tyre Stockpile Fires	275	112	116	503
Pyrolysis	269.6	156	40	465.6
Tyre Derived Fuel	630	222	30	882

***Source**: Adapted from Chang & Gronwald, A Multi-Criteria Evaluation of the Methods to Recycle Scrap Tires*



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