Waste to Resource Strategy

Gold Coast City Marina & Shipyard

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Attribution
Please cite this report as: Herbst, J. & Barnes, L. (2021). *Waste to resource strategy*. Brisbane, Queensland: Centre for a Waste-Free World, Queensland University of Technology.

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This research was commissioned by Gold Coast City Marina and Shipyard (GCCM) and Innovation Connections. The purpose of this report is to assist GCCM in diverting waste from landfill and exploiting value from conservation of resources. Any views and recommendations expressed in this report do not necessarily reflect the views of GCCM and the Commonwealth or indicate a commitment to a particular course of action. GCCM and the Commonwealth make no representation or warranty as to the accuracy, reliability, completeness or currency of the information contained in this report.

Acknowledgements

We wish to acknowledge the contributors to this project. Partners included Gold Coast City Marina & Shipyard, the Centre for a Waste-Free World, QUT, and the Department of Industry, Science, Energy and Resources Entrepreneurs Programme, Australian Government, through an Innovation Connections grant. Moreover, the Queensland Government and Gold Coast City Council supported the Marina's waste-free ambitions through attending workshops and linking the Marina with ASPIRE, the online marketplace for the circular economy. Tenants, staff, and suppliers importantly laid the groundwork by sharing their insights and making daily change. Thank you to all boating industry members for actively working towards a better environment.

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Introduction

Located along the magnificent Southeast Queensland coastline, the Gold Coast City Marina & Shipyard (GCCM) encompasses 17.5 hectares of land on the Coomera River. This facility includes a 300-tonne straddle lift, 50,000 m^2 of hardstand, 75-metre work berths, and an array of undercover work areas and refit sheds that cater to more than 90 on-site businesses. These companies employ more than 700 marine tradesmen who service all types of watercraft, ranging from small jet skis to superyachts. GCCM has earned its premier status as the most awarded marine facility in Australia due to executing on its mission to deliver comprehensive and quality services at its facility. This pledge aligns with GCCM's commitment to integrate world-class standards in sustainability.

Environmental initiatives that it has implemented thus far include rainwater harvesting, collection of all regulated solid and liquid waste for resource recovery, and treatment and recycling of all watercraft washdown water. GCCM also installed two solar arrays to harness renewable power for its operations and positioned a floating Seabin dockside to filter substance runoff.

On shore, dedicated bins are situated throughout the complex to segregate multiple material streams and divert them from landfill by the general waste contractor. These collection bins capture paper and cardboard, plastics, metals, and glass for recycling. Sweep Marine Services manage liquid waste streams for recycling such as fuels and lubricants.

Results of GCCM's efforts are shown by gaining consecutive recognition as a Clean Marina based on independent audits. These credentials extend to being awarded level 3 clean marina and fish friendly rankings by the International Clean Marina accreditation programs by the MIA. To further protect fish species, GCCM bans fishing on its site with signage posted to all interested boaters to learn about local types of fish, limitations on catch, and other relevant fishing guidelines. GCCM has signed up to the MIA (2021) commitment to eliminate all single-use plastics by 2025.

GCCM satisfied an external assessment of its operations, facilities, and customer service to retain international Five Gold Anchor accreditation. Although the Marina has achieved an impressive record of environmental and social responsibility to date, management strive for continuous improvement. GCCM recognises one of the primary areas where it has room for improvement is waste management.

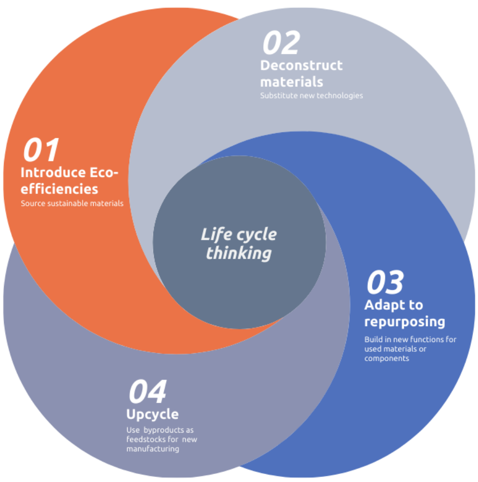
There is a lot of debris that accumulates behind the scenes in the warehouses and shipyard to put vessels in shipshape condition. When boats are taken apart, excess waste is created that cannot be placed in conventional recycling bins or treated in safe and environmentally friendly ways. This problem is symptomatic of larger international problems to source adequate solutions for the increasing number of retired boats and boat parts that demand a better resting place than landfill.

Boat repair and maintenance effect surrounding coastal environments. Facility operators are often unaware of the environmental risks posed by their practices regarding wastes; in particular, the harm caused by toxic paint chips, paint residues and other solid and liquid wastes containing heavy metals, acids, oil, hydrocarbons, and marine pest species (EPA Tasmania, 2020). Key to this transformation is finding solutions to lower the impacts and turn waste into valuable resources through innovation and technology.

Current challenges that have been identified on site are:

- Lack of access to recycling options across the yard due to the large area of GCCM and limitations of only having mainstream recycling options
- Lack of understanding by businesses about waste resources and how they can be recycled or repurposed in other ways
- Lack of ability to translate the initial costs of investment into alternative waste management options for short-term savings in lower landfill fees and long-term savings in finding markets for reusable materials

GCCM has stepped up to heed that advice, joining fellow industry leaders worldwide that are taking initiatives for responsible consumption and production. It facilitated an engagement workshop with its key target publics at the end of July to determine optimal and concrete pathways to bring this agenda to fruition. This report was prepared of the research findings. It outlines a plan, spanning design, use, disposal, and collection of end-of-life (EOL) materials for repurposing that is fundamental to drive linear thinking towards actualising meaningful circular practices over one, five, and twenty-five years.



Stewardship principles and practices

GCCM aims to realise its vision of waste stewardship across all aspects of operations, and act respectfully and inclusively of the wider community. The organisation already complies with statutory standards to curb air, water, and noise pollution. It similarly directs tenants to conform with their environmental authority license (City of Gold Coast, 2019) that prescribes environmentally relevant activities for boat maintenance or repair.

Management underscores and reinforces GCCM's commitments on a regular basis via newsletters and committee meetings. They want to set a higher level for future performance, as stated, that reflects UN Sustainable Development Goal #12 to build Sustainable Consumption and Production patterns into operations. By doing so, it will invariably reduce greenhouse gases for Climate Action as well, Sustainable Development Goal #13 (United Nations Department of Economic and Social Affairs, n.d.).

Scientists are concerned that unwanted boat parts decompose into microplastics and leach toxins that drift with currents at sea, harming coral reefs and species living in marine habitats. Health hazards are documented from other formerly used materials in boating that include asbestos and lead. Ongoing practices still present dangers. Dust from grinding fiberglass boats on land alone can block passageways in people's lungs, eventually dispersing into waterways where the microparticles affect plants, animals, and can be transferred up the food chain (Ciocan, 2020).

Localities are grappling to figure out methods to deal with EOL materials from boat refits. Disposal of boat parts in shipyards to be forwarded to landfills cannot be the answer because leaching of hazardous chemicals in soil or nearby waterways brings unnecessary repercussions. Boats are composed of engines, anchors, masts, and winches, to name a few parts, that can be reused if they are in adequate condition. Metals may be recycled such as stainless steel and aluminium. Electrical and electronic equipment can also be reused or disassembled for their finite metal components. Batteries and liquids including lubricants and fuels may be recycled. And some remaining materials such as timber can be segregated and resold (Dejhalla & Legović, 2018).

Literature review

BOATING INDUSTRY & WASTE DISPOSAL

This is good news considering the magnitude of figuring out what to do with parts from just one supersize vessel, for example. Moreover, recreational boats which have become very popular as a weekend activity for families reveals a different EOL scenario that has to be managed differently. These boats are usually manufactured from fiberglass laminate because it is mechanically strong, reduces maintenance, and allows easy repair. It is very difficult to find a post-consumer solution for this material. Fiberglass has been used in mass production of boats since the 1950s although it is a health hazard when inhaled (OSHA, 2009), and it creates an environmental risk. The consequences are so severe that the EU prohibited discarding of fiberglass in landfill since 2015 (Directive 2008/98/EC), but this substance remains in production, resulting in oversupply.

While newer boat laminates have evolved, these composite resins that bond with the glass (epoxy, polyester or vinylester) lend greater durability except they need to be chemically separated to break down and the microparticles might contain phthalates, chemicals that also cause detrimental health issues. Most boat hulls have other obstacles with applications of toxic paints or antifouling coatings that are formulated from biocides. Two substances, tributyltin (TBT) and triphenyltin (TPT) were banned by global maritime treaties by the International Maritime Organization (IMO), effective in 2003. TBT was correlated with shellfish deformities, and bioaccumulation (Champ, 2001). Recent localised studies in the UK tracking the marine effects of old boats in waterways show accumulation of lead, copper, and zinc levels exceed guidelines for environmental quality (Ciocan, 2020). For these reasons, organic compounds, heavy metals, and flame retardants have been discouraged or restricted to prevent contamination of aquatic habitats and humans. Now it is recommended for manufacturers to switch to less environmentally persistent alternatives.

During boat maintenance, repair or refit, adequate health and safety measures should be followed to avoid personal risks and prevent dispersal of the same pollutants that threaten ecosystems. Qualified companies should clean and dismantle vessels to minimise issues and find reuses for viable components. Thus, a superstructure and decks that are in good condition should be reused. Fiberglass can be crushed, ground, and remixed with fillers to form concrete. Electrical and electronic equipment should be properly handled for recycling, flushing engines first of fuel and lubricants (Dejhalla & Legović, 2018). Table 1 lists all the main sections of a boat and associated materials that can be repurposed.

What is less apparent is who should pay for the waste mitigation. Policymakers have wrestled with figuring out legislation to decide who will bear this expense. The Polluter Pays Principle (PPP) has been accepted as policy in places which advocate pollution should be borne by those who cause it. For those governments, taxation is frequently implemented as an instrument to control environmental burdens (OECD, 1972).

Alternatively, economists argue the burden of financing the costs for disposal of boating waste should be passed on to manufacturers. They prefer to factor this expense in to the price of a new boat, justifying that the externalities of environmental costs should be internalised in the price of goods. Legislatures that back this argument deem the user should pay. Those governments will hold society responsible for environmental benefits rather than suffer from its degradation (OECD, 1995). The European Boating Association (EBA, 2020) agrees with this philosophy. They want to enforce a mechanism whereby boat builders will collect funds at time of purchase that can be allocated for responsible waste management later when it is warranted.

Lacking governmental regulations, GCCM needs to consider how to apportion costs of boating waste that can be offset through designing and building boats that incorporate sustainable materials, and it wants to influence standards for sustainable procurement, utilising landfill levies towards improved waste practices, and changing behaviour to eliminate individuals’ throwaway mentality. It decided to take a grassroots approach to forge its own plan by convening with its stakeholders. A workshop was held to co-design a plan with tenants, government officials, and academics.

Table 1. Boat parts, materials, pollutants, and recycling options, adapted from (Dejhalla & Legović, 2018)

Boat Part	Material	Pollutant	Multiple Use / Recycling
Hull	Antifouling paints Gelcoat	Tributylin (TBT), copper, irgarol, diuron, lead, zinc, zineb	All listed pollutants are poisonous and need to be removed prior to disposal or reuse of the fiberglass hull
	Fiberglass laminate		Commercially justified technology is limited & there is low energy value
	Thermoplastics	Pigments with cadmium and lead for paint stabilization	Recycling is limited & depends on material levels
	Wood	PCB (polychlorinated biphenyl) from paints and bonding materials	Materials which contain PCB should not be recycled
	Zinc anodes	Zinc, cadmium	Zinc anodes often contain cadmium in traces, which should be considered in recycling
Superstructure	Deck		If wooden – for energy
	Fenders	Lead in PVC (polyvinyl chloride) plastics	PVC can be recycled if sufficient quantity & quality is recovered
	Sandwich construction with foam core	CFC (chlorofluorocarbon) and HCFC (hydrochlorofluorocarbon) gases	Unsuitable for recycling
	Mast		If metal – for recycling If wooden – for energy
	Sails		If plastic & maybe If textile
Furnishings	Ropes		If plastic
	Windows	PCB in sealing of glass to frames	Not PCB material
	Textiles	Flame retardants	Unsuitable
	Wood	White paint may contain lead	Energy
	Paint	White paint may contain lead	No
	Toilet		Remove for reuse
	Stove/oven		Remove for reuse
Engine	Engine parts		Yes
	Starter		Remove for reuse
	Batteries	Acid and lead	Yes
	Iron parts		Yes
	Oil	PAH (polycyclic aromatic hydrocarbons)	No
	Boat propeller		Remove for reuse
	Boat transmission gearbox		Remove for reuse
Electronic equipment	GPS receiver, chartplotter, radio	Flame retardants	Depends on its condition

Methodology for stakeholder engagement

A partnership co-design toolkit was utilised to collaborate with GCCM's partners during a three-hour 'Closing the loop on waste @GCCM' workshop that was held on 29 July 2021. The P.ACT framework for this stakeholder engagement workshop was designed by MIT's D-Lab and SEED, a global project for social entrepreneurship and ecosystem development (MITD-Lab, 2020). It is targeted at organisations that want to initiate value chain partnerships. Each tool works to bring the partners closer, to build a strategic action plan, and to embark on tactics to maximise success—in this case for more prudent handling of waste at GCCM.

Participants included four researchers from QUT, six GCCM personnel, two Gold Coast City Council officers, one Queensland Government representative, and sixteen industry members. Meetings were arranged in August and September with five tenants who could not attend the workshop and adhered to the same open-ended format of the workshop to collect data.

WORKSHEETS

A packet of worksheets was distributed to all participants to complete while everyone interacted in a roundtable discussion. These questions were incorporated in the kit:

1 Drivers

Who are the actors and why does everyone want to engage in waste management and resource recovery?

Identify what is significant regarding better waste disposal methods.

2 Material waste

What are the particular waste streams of the businesses at GCCM?

Describe which products and byproducts need to be removed from the premises.

3 Motivation

What are the waste issues that tenants want to resolve?

Discuss the risks and rewards in waste loss and how to generate more value from these resources.

4 Value proposition

What can the partners contribute to exchange value that is beyond what is already being offered to beneficiaries?

Articulate the goals and assess the capabilities to fulfil these objectives.

5 Challenges

What criteria are missing? How can these gaps be overcome?

Consider whether innovative processes in research and development might have to be deployed to resolve waste issues.

6 Impact targets

What kinds of impacts does everyone want to create? For whom? And how do we want to monitor results?

Define the inputs as measurable investments, the outputs as tangible products or services, the outcomes as positive effects, and the broader impacts as larger visions to tackle global problems.

7 Commitments

How will the partners deliver the value proposition?

Roles and responsibilities must be pinpointed to get buy-in for the program. Partners were lastly reminded about the need to manage foreseeable risks and formulate a governance charter for project coordination.

Participants shared the initial steps to co-design a strategic action plan —learning, imagining, and creating new pathways to reach higher waste management and resource recovery goals. In addition to ascertaining this primary research from the workshop, a pool of secondary research was collected from government reports, peer-reviewed journals, and industry databases. Wanless Waste Management, the contractor for GCCM, furnished a breakdown of their general and recycled waste streams for the 2020-2021 financial year, and the Gold Coast Region Scouts accounted for GCCM's overall contribution of plastic and glass bottles and cans to the container deposit scheme (CDS) for recycling.

In addition, GCCM registered for the ASPIRE platform. It functions as a virtual network whereby tenants can exchange their unwanted resources such as e-waste with businesses that want these products to revalue them in the marketplace. Other initiatives will be rolled out over the next six months. The Marina and research team will be in charge of evaluating and reporting back to all partners afterwards about what was achieved, and to discuss any adjustments or new measures for future success.

Findings and material analysis

Data collected from tenants about their material waste streams is seen in Table 2. The businesses ranked their refuse according to the volume which is output.

Table 2. Material waste streams

Types of Businesses	Largest waste streams	Medium waste streams	Smallest waste streams
Shipwright, yacht design & repairs	Resins, fibreglass, epoxy filler, caulking, paint, timber, textiles, metal alloys (aluminium & stainless steel), appliances and other boat parts, rigid & soft plastics	Tins, bottles, timber, paper & cardboard & office supplies (printer cartridges, batteries & stationery)	Mixed residual waste (paper towels, organic food waste & packaging)
Metal fabrication	Metal alloys, plastics, textiles	Packaging (cardboard, plastic & pallets)	Mixed residual waste & cleaning solvents
Upholstery & interior fitout, trimming & sailmaking	Mattresses, foams, carpet & timber	Canvas & other fabrics w/polypropylene	Mixed residual waste, rags, glues, metal drums & other packaging
Paint/antifouling	Metal tins, LDPE film, solvents, paints, volatile organic compounds, cardboard & paper	Sandpaper, adhesives (paper & PVC)	Mixed residual waste & PPE
Signage & wraps	Silicone film & paper	Cardboard & PVC adhesive	Mixed residual waste & plastic bottles
Electrical & electronics	E-waste	Rubber, copper cables	Packaging & mixed residual waste
Mechanical & maintenance	Contaminated solids & liquids (water, marine grade oils & fuel) & filters, parts	Rubber, plastic sheets & parts from vessels	Mixed residual waste, cleaning solvents, PPE & solar panels
Marine debris	Polystyrene & other plastics (e.g., HDPE, LDPE)	Oils, fuels & solvents	Mixed residual waste

Table 3 provides a snapshot of the quantity and types of waste that were being removed from GCCM by the waste management company in tonnes of general waste versus resources diverted for recycling. The volumes of recycling materials were relatively stable over the last financial year. Metal is forwarded to another company and is not included in the chart.

Table 3. Wanless Waste Management accounting for FY 2021

Waste Report Financial Year - 2021 - Gold Coast City Marina & Shipyard
Total Volume

	Jul-20	Aug-20	Sep-20	Oct-20	Nov-20	Dec-20	Jan-21	Feb-21	Mar-21	Apr-21	May-21	Jun-21	TOTAL
General Waste	632.20	556.80	725.00	626.40	547.00	539.40	549.00	632.00	728.60	774.40	686.80	944.40	**7,942.00**
Cardboard	119.00	112.40	293.00	224.80	236.80	243.40	224.80	224.80	307.20	224.80	224.80	329.00	**2,764.80**
Scrap Metal	30.00	60.00	30.00	30.00	30.00	30.00	30.00	0.00	0.00	0.00	0.00	0.00	**240.00**
Timber	72.00	48.00	48.00	72.00	48.00	48.00	72.00	48.00	72.00	48.00	48.00	72.00	**696.00**
Liquid	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Plastic	25.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**25.00**
Total Volume	**878.20**	**777.20**	**1,096.00**	**953.20**	**861.80**	**860.80**	**875.80**	**904.80**	**1,107.80**	**1,047.20**	**959.60**	**1,345.40**	**11,667.80**
Volume Recovered from GW	**341.39**	**300.67**	**391.50**	**338.26**	**295.38**	**291.28**	**296.46**	**341.28**	**393.44**	**418.18**	**370.87**	**509.98**	**4,288.68**
% Volume Recycled	66.89%	67.04%	69.57%	69.77%	70.80%	71.18%	71.16%	67.87%	69.75%	65.98%	67.08%	67.71%	**68.69%**

A total of 19,488 bottles and cans were also collected by the local Scouts association since August 2020 for recycling through the CDS as depicted in Table 4. The highest number of returns occurred in November 2020 and May 2021 when over 5,000 eligible containers were returned.

Table 4. Gold Coast Scouts collection of bottles and containers for recycling

Scouts	Aug-20	Nov-20	Jan-21	May-21	Jul-21	TOTAL
Bottles and Containers	3,856	5,287	1,901	5,177	3,267	19,488

During the interviews, tenants said they were uncertain whether their own waste management contractors were taking measures to act responsibly. For example, a paint supplier wanted to know what happened to his metal cans once they were picked up for shredding and supposed recycling. Thus, traceability of EOL materials that are collected for recycling is an important question that has to be resolved.

Another interviewee, a boat builder, emailed a supplier to enquire whether it would be possible to rewash and reuse metal drums that house oil once they are emptied. That would avoid the need to manufacture new drums altogether, saving on virgin materials and energy.

> *"I suppose the question to ask is what's the current procedures being used with new drums delivered for filling. There would have to be a process of validated cleanliness on delivery to the oil batching facility after the manufacture of the drums. Could the recycling of the empty drums be put through this 'cleaning' process? I know there would be commercial push back from the drum manufacturer & all the players in the material supply chain (loss of existing business). Looking forward to connecting with the Ampol business manager to explore any opportunities. If thought out properly, the potential is to reduce the cost of oil supply by reducing the packaging costs (even if it's only a small amount) as well as making a green statement for a business group that is universally viewed as a carbon producer rather than a reducer (Seapower Marine, respondent 2)."*

The lid has been opened to explore options for change. The stakeholder engagement workshop provoked other spinoff conversations around how to get involved in boating businesses that are based on renewable power to tap into cleaner fuel sources. A yacht designer said he is fielding requests for hydrogen-powered vessels. Hydrogen only produces one waste product—pure water. Several GCCM members have formed a consortium to develop a hydrogen ecosystem in Australia. They invited people who are interested to join this venture.

> *"It is great to hear such excitement for hydrogen-powered marine vessels. Hydrogen fuel cell marine vessels is an area not yet well explored in Australia, but one with enormous potential…I work for H2X Global, specialising in hydrogen technologies and development. We are a newly establishing EV manufacturer in Australia, with a particular focus on FCEVs [fuel cell electric vehicles]. We are still in the planning phases, but together we have connected chains of FCEV manufacturing, green hydrogen production, distribution, transport and storage, as well as hydrogen refuelling together (H2X Global, respondent 1)."*

This next section analyses post-consumer treatment of specific waste materials locally and globally. It is a reference of ideas to remediate types of waste at GCCM.

01 Plastics

It is estimated that 2.54 Mt of plastics waste was generated per capita in Australia in 2018-2019 (Blue Environment, 2020). There are low rates of recycling for this waste, below 13 percent, but the amount has marginally increased with diversification of end uses for waste products. Conversion of plastics waste into fuel for energy is a particularly growing market. In 2018-2019, three percent of plastics waste was recovered as solid waste for this purpose.

Previously, Australia depended on exporting the bulk of its plastics waste to China. After China imposed a stringent National Sword Policy in 2018, it curtailed imports on most plastics and other materials that were destined for recycling. Vietnam, Malaysia, Indonesia, Thailand, and other Asian nations capitalised on the opportunity to fill this void, but they have borne the brunt of a massive clean-up issue that is literally choking species among mounting bottlenecks of plastics waste, and the oversupply led to a crash in prices for Australia's recyclables trade (MRA, 2018).

Investment is required to develop efficient technology to handle this surplus. Many well-known brands are at least starting to set increased targets for recycled content in manufacturing their products. Of newly produced plastics, however, only four percent contain recycled content from imported and domestically manufactured supplies (Schandl et al., 2020). There is obviously a long road to actualise this intent since Australians consumed around 3.36 Mt of plastics in 2018-2019.

It is also incumbent upon consumers to limit their usage of plastics that they can feasibly reduce because COVID-19 has undermined certain efforts. There has been a growing demand for PPE, plastics made for personal protective equipment. Nonetheless, more individuals and companies are getting involved in recycling bottles and films, HDPE and LDPE, respectively (NSW EPA, n.d.). Melting of these types of thermoplastics into pellets for remanufacture helps to make recycling more economically viable. More strategies are urgently called for considering approximately one-third of plastics including packaging have a lifespan of less than one year and Australia's landfills are bursting with more than 50Mt of plastics. There is significant accumulation of plastics in the built environment and consumer products as well with stocks predicted at 29.1 Mt. Collection is very low at 17 percent, and there are sorting and reprocessing losses that happen further downstream (Blue Environment, 2020).

Plastics (continued)

01

Strategies have been extended to heighten local collection and recycling rates with the container deposit scheme that will become nationwide by 2023 (Schandl et al.., 2020). It offers a small rebate for returning plastic bottles in conjunction with glass and aluminium cans. GCCM cooperates with the local Scouts association to oversee a joint CDS recycling program as stated.

GCCM launched a Plastic Free campaign in July 2021 to stimulate site workers to eliminate usage of unnecessary single-use plastics (Plastic Free Foundation, n.d.). The campaign was promoted on their facebook site. It drew both positive and negative attention from viewers who commented on the laudable efforts of GCCM, but the plastic wrap draped over a ship refurbishment seemed inconsistent with the recycling message. After it sparked criticism, management explained that the wrap would be removed for decontamination and recycling by the waste contractor when the job is finished which has happened.

02

Paper and Cardboard

In 2018-2019 an estimated 5.91 Mt of scrap paper and cardboard was nationally generated, of which 3.86 Mt included packaging and the rest was mostly confined to office paper, tissue, and newsprint (Blue Environment, 2020). Figures show falling consumption in newspaper purchases at 16.6 percent from 2017-2019 due to today's consumer preference to access digital sources of information (IndustryEdge, 2020). Reductions in recycling rates of paper and cardboard are believed to reflect this global phenomenon.

Although recycling rates have somewhat lessened over a decade from 66 to 60 percent in 2018-2019, the market for scrap paper has been impacted by Asian bans on waste imports (Blue Environment, 2020). In the future, it will be affected by Australia's pending waste export restrictions. Australia faces a looming problem in how it can find more productive uses for these resources in a domestic marketplace that is saturated, particularly since most paper and cardboard have a lifespan of less than one year.

Nevertheless, collection is efficient at 64 percent, underpinned by a healthy appetite in the commercial and industrial market for cardboard. And recycled content of paper and cardboard is approximately 52 percent. Cardboard has the highest intake of recycled content for imported and domestic stocks. Pet litter sits at the lowest end of reprocessing at less than one percent. Tissues that flow through sewer systems are being modelled for future incorporation into biosolids (Blue Environment, 2020).

At GCCM, paper is allocated for recycling, but it is not subdivided to get better results. Another problem is the inability to separate combined paper and plastic products, for example, polyethylene linings in coffee cups, and boat hull wraps that consist of films which adhere to silicone-backed paper.

03 Metals

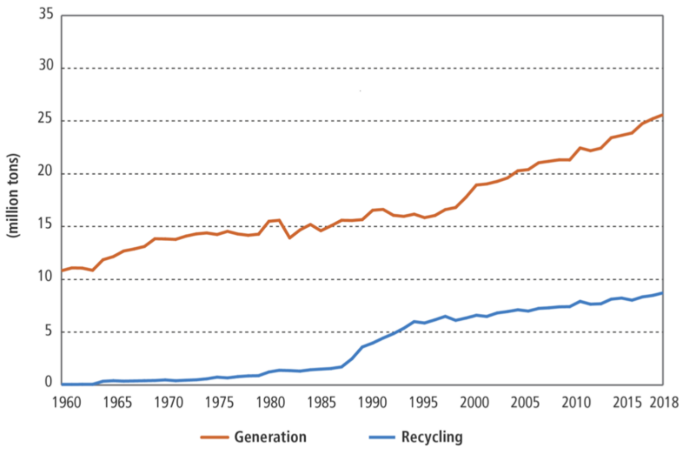
Metals are in high demand for industrial production. Stainless steel, for instance, is a ubiquitous material used in boat building for fabrication, trimming, welding, soldering, and surface coating. Aluminium is commonly used for construction, or electric transmission cables. Copper acts as a good conductor among other applications.

In general, metallury is extremely profitable, and it is one of the most regulated industries in the world, but it poses serious environmental and health downsides. Sustainable management would mean fewer metals are extracted from their ore state to be modified for use, thereby lowering the energy strain and water consumption for cooling. Metallurgy is not only highly resource intensive, but production and metal finishing results in high water pollution that involves high costs for subsequent water treatment (Nistor & Herman, 2016).

To switch to greener manufacturing, the metal industry must therefore receive appropriate policy and price signals for secondary repurposing over constant extraction of primary, and at times, rare metals (Huebsch, 2017). Besides economics, the only real barrier for recycling is that some recycled metals do not maintain their original property of malleability. Yet, they can still be recycled into different products, saving 95 percent less energy than new metal production. Recycling generates $800 million USD. Scrap metal recycling programs are often run by charities to fund outreach services.

Non-ferrous metals such as steel and aluminium have higher recycling rates than ferrous ones. According to the U.S, EPA (2020), statistics show metals account for 12.6 percent of recycling in waste municipal waste streams, or 69.09 Mt of waste. Even though metals make up only 9.5 percent of municipal landfilled waste at 146.12 million tonnes, some states and local governments recognise it is their duty to emphasise recycling, so they have passed laws to mandate it. Institutional support can further help to ensure investments in physical infrastructure facilitate this transition. Figure 1 shows recent metals generation still surpasses recycling due to demand.

Figure 1. Metals generation versus recycling rates, (U.S. EPA, 2020, p. 62)



03

Metals (continued)

In Australia, steel comprised 86 percent of metal consumption and aluminium represented 8 percent (Blue Environment, 2020). The remaining 6 percent was mixed with copper totaling 8.09 Mt of metal consumed in 2018-2019. Waste generation of metals rose by approximately 39 percent while recycling rates climbed to 90 percent, the highest of all material streams at around 5.6 Mt per capita. Metal recycling is prolific in every state and territory, but it has decreased due to declining global prices. Australia is reliant on export markets because there are limited smelters here, so it exports 93 percent. This high number reflects effective systems are in place for collection, sorting and reprocessing in this country. Metals are abundant in electronic and electrical equipment which is touched on again in a later section.

04

Organics

Organic waste is mainly made up of food and garden organics, biosolids, and timber. Of these material streams, two are pertinent to the Marina—food waste and timber. This section will concentrate on organic food waste. A separate section is devoted to timber.

Nearly all organic material can be decomposed by composting to rejuvenate soil health and productivity. Historically, urban landscapes appropriated the majority of compost products. The agronomic value of compost has steadily increased its geographic reach, but logistical costs impede expansion of agricultural markets outside of cities.

Calculations for all food waste (excluding on-farm and many food processing operations) show approximately 5.09 Mt was generated in 2018-2019 in Australia. 22 percent of this waste was degraded through composting. Approximately 87 percent was deemed nonhazardous material which allows it to be subject to treatment (Blue Environment, 2020).

There is ample opportunity to boost recovery of organics at GCCM from food waste, especially to eliminate contamination by segregating it from plastic, glass, and chemicals. If that happens, then more of this material can undergo anaerobic digestion. Some of this waste stream can also be used to generate electricity and produce digestate, a byproduct which is equivalent to fertilizer. The National Food Waste Strategy has set a goal to cut food waste in half by 2030 (Australian Government, 2017).

Many local governments including the Gold Coast City Council are providing segregated green bins for its collection although locations are distributed around the city. Commercial recovery services are also available in many jurisdictions. The Council does not provide expanded food organics and garden organics (FOGO) collection services that have been enacted in most of the other states (Blue Environment, 2020).

05 Glass

Glass consumption was approximately 1.21 Mt in 2018-2019, and nearly 1.1.6 Mt of glass waste was generated per capita in Australia (Blue Environment, 2020). This latter figure represents a slight increase from the previous year, mirroring the small rise in the recycling rate to 59 percent. On the other hand, glass packaging has dropped due to competition from plastics, but its market share has somewhat rebounded. Almost all recycled content of post-consumer glass is actually used in packaging.

Further, the rate of recycling stayed reasonably consistent despite the low commodity value of glass per tonne compared to cardboard or plastic (Blue Environment, 2020). It is difficult to recover glass from mixed waste loads. Glass can easily shatter and contaminate mixed waste, and it cannot be segregated at material recycling facilities (MRFs) that lack the technological capabilities to perform this task.

CDSs are better equipped to properly sort glass ‘cullet’ than traditional collection depots which suffer extra losses during sorting and reprocessing. On the positive side, there is future potential to raise recovery rates in Australia from the current 27 percent level to increase recycled content in glass since the new owners of national glass manufacturer, Visy, committed to this pledge (Blue Environment, 2020). Another boost lies in construction. More projects are mixing recycled glass with sand to complete building works. It is crucial to allocate recycled glass in the built environment because only a small amount is shipped overseas, and accumulated stocks of glass in Australian landfills topple 20 Mt.

06 Fiberglass

Older fiberglass boats are hard to dispose of, and they have limited viable afterlife markets. Technical solutions exist to recover fibers through pyrolysis, or to obtain fibers and resins through solvolysis except the processes are expensive and not at commercial scale (IMO, 2019). Health and safety problems occur with other methods.

Hazardous dust and glass fibres which are produced during grinding, shredding, or burning pollute. Dust will float, adding to surface pollution, whereas glass fibres are heavier and will settle on the ocean floor. Aquatic life is likely to ingest this sediment which can move up the food chain as mentioned (Ciocan, 2020). Many countries have searched for ecological and economical solutions to this problem.

06

Fiberglass (continued)

The Japan Marine Industry Association (JMIA) started to collect EOL fiberglass boats by adopting a voluntary recycling scheme back in 2005. It is founded on the extended producer responsibility (EPR) principle to hold manufacturers responsible for looking after their wares. Testament to the success of the program is the high rate of recycling over ten years. Only 12 to 13 percent of the total weight of EOL boats went to landfill despite dismantling being a cheaper option than recycling (Saltmarsh, 2017).

Other countries are transitioning to EPR initiatives. France enacted an environmental levy. The Federation of Nautical Industries (FIN) used these industry funds to establish a network of centres around the nation that remove, dismantle, and dispose of EOL leisure fiberglass boats. The wood and metal are recycled from the boats, and composite material is burned as fuel in cement kilns (APER, 2014).

A unique twist is the case of Bathô, a small social enterprise that started up a boatyard in France. It acquires abandoned and derelict boats for conversion into playground equipment, outdoor bars, and guest houses. Disadvantaged workers are trained in boatbuilding skills, and following cleanup, structural fit outs, and cosmetic changes, old boats get a new lease on life on land (Loibner, 2021).

Norway developed its own innovation for circularity and functionality. It incentivises boat recycling by funding companies to recycle them, so it rewards individuals by paying them around $100 USD to return recreational boats. Norway's advanced industry produces two grades of "ecofiber" which is created by milling fiberglass flakes. The first grade is a composite of fiberglass while the second one contains additives from rubber, plastics, wood, and paint that are used to remanufacture nonstructural items such as tabletops or furniture for rest stops (Validé, n.d.)

Germany outlawed sending fiberglass to landfill in 1996, but it had trouble finding economical applications until mechanical coprocessing in cement kilns looked like a fruitful option (Loibner, 2021). This fuel source has replaced petroleum coke, coal, and natural gas. After burning, only slag from incineration requires recycling, and slag is a safe substance. Cement trials have also been conducted by the Rhode Island Marine Trades Association (RIMTA, 2019). Another option that has been explored is to incinerate fiberglass for waste to energy. However, that process produces toxic emissions so it must be carefully contained and monitored.

06 Fiberglass (continued)

Composites are the most viable solutions invented thus far. Pure material can be extracted by grinding cured fiberglass laminate into a recyclate to be mixed with resins for filler in tarmac, for example (IMO, 2019). The company, Eco-Wolf (n.d.), set up recycling systems, feeding structural fibers with composites in moulds to form boat and deck cores and to make other products in thermoforming ovens. They also use fibers for spray-up or hand layup applications. Italy is experimenting in this area by blending fibers with used resin and virgin prepolymer resins to produce new composites that appear sustainable and profitable (Loibner, 2021).

Northern Light Composites (nlcomp, n.d.) in Italy has come up with an ingenious alternative to avoid fiberglass. They replaced the glass with flax fiber to build an Eco Racer 769 sailboat and ecoPrimus youth dinghies. Extra layers of flax fiber are padded together to get equivalent strength to fiberglass. Although the structure needs to be wrapped with vinyl to protect it from the elements of sea water and UV light, and the edges must be sealed with resin to avoid delamination, these boats offer advantages. They can be repaired or recycled with vinyl film at EOL. The skin of their racing sailboat is made from recycled carbon for an aesthetic finish, and it incorporates vacuum infusion technology to maximise the fiber to resin weight ratio. Nlcomp is currently piloting the incorporation of other materials, using PET foams and thermoplastic resins to manufacture larger boats. Thermoplastics allow chemical separation by soaking the composite in solvent as opposed to needing to subject it to physical deconstruction using heat.

07 Textiles

In 2018-2019, around 780 kt of textile waste was generated per capita in Australia which is on the incline from 2016-2017 at 779 kt (Blue Environment, 2020). The recycling rate is staggeringly low at 7 percent. Even though recovery is estimated at 22 percent, most textiles are shipped overseas for recycling. Australia needs to manage this issue at home and minimise what is diverted to landfill because decaying textile waste produces methane gas and leaches toxic dyes and chemicals into the soil and groundwater.

There are diverse ways that textile waste may be reprocessed at their EOL because they cover a range of products including mattresses, carpets, and furniture coverings to name a few of their applications. At GCCM, tenants provide textiles in servicing the internal and external fitout and refurbishment needs for customers’ vessels (in this context, the textiles exclude clothing items).

07

Textiles (continued)

Researchers have been formulating ideas to redesign or decompose textiles back to raw materials that contain cotton or polyester fibers for circularity (BlockTexx, 2020). However, marine grade textiles are manufactured or coated with polypropylene to protect fabrics from the harsh ultraviolet rays of the sun and corrosive sea salt which precludes this process. Innovation is unfolding to meet the challenge of breaking down even this synthetic which is a form of plastic for reuse.

Large-scale manufacturers such as Sunbrella supply outdoor fabrics to withstand the elements recognise their role in the product chain (Sunbrella, 2021). They are beginning to own up to their responsibility by offering a takeback scheme that is currently available in the U.S. If textile waste can be captured after use for rerouting to manufacturers as feedstock for repurposing, it will accelerate the transition to a circular economy.

Mattresses represent another product category that has become a vast disposal issue. An average of 1.6 to 1.8 million mattresses are disposed of annually in Australia alone (Planet Ark Recycling 2020), but only a small percentage are recycled. Most of them get shredded and sent to landfill where each one takes up .75m^3 of space. Mattresses contain known carcinogens. They leach other hazardous chemicals, particularly in the polyurethane foam, adhesives, and flame retardants. Hence, recycling procedures must be carefully enacted to protect the health and safety of workers as well as to mitigate risks to the public.

There is potential to scale value from recovering certain resources from unwanted mattresses, especially due to large rates of commercial turnover. Refurbishing and repurposing the metal springs, natural fibre, and residual waste could save on virgin material, reduce emissions by 90 percent, and save landfill costs. Additionally, it is feasible to create composite and standalone products such as: foam insulation, pressed and moulded building panels, asphalt and road furniture, resin/filler additives, and it is possible to investigate research to combine lignocellulosic biomass with other waste streams for infrastructure or carbon-neutral energy (Barner et al., 2021).

Regarding flooring, Interface carpets has redesigned the concept of selling carpets for use and subsequent disposal. The organisation's global program has become renowned for offering an integrated collection of resilient flooring products that are carbon neutral and replaceable (Interface, 2021). Their brands are supplied as modular systems which are available in carpet tile, luxury vinyl, and rubber flooring materials that are welcomed back by the manufacturer at the EOL stage.

08

E-waste

Advances and the fast pace of technology has accelerated turnover of electrical and electronic equipment, resulting in a lot of e-waste. In many jurisdictions incineration or landfill disposal is no longer permitted since it is hazardous. E-waste or waste electrical and electronic equipment (WEEE) is quite valuable to divert from landfill because it contains precious metals such as gold and silver. Extracting these metals though has to be managed safely.

Metals can be industrially separated using pyrometallurgical, hydrometallurgical and electrometallurgical processing. Pyrometallurgical processing is mechanical. It is an economical and eco-efficient way to initially segregate precious metals such as gold and silver into the base metals copper, lead, and nickel. Then hydrometallurgical, or less often, electrometallurgical processing is employed to recover pure base from precious metals (Khaliq et al., 2014).

Many developing countries do not have legislative standards, knowledge or means to enforce safety protocols for removal. Frequently citizens will deconstruct e-waste to obtain metals without using gloves or taking other precautions. In developed nations like Australia, obstacles are mostly confined to having inadequate collection, transport, and readily available technology to extract the metals and forward them for smelting and refining (WHO, 2021). Investment in broader domestic smelting and refining facilities would be a shrewd financial maneuver to treat molten metals for remanufacturing.

Printed circuit boards (PCBs) inside electrical and electronic appliances consist of around 40 percent metals, 30 percent plastics and 30 percent ceramics (Ogunniuyi, Vermaak, & Groot, 2009). PCBs are coated with base metals to make them conductive, and there are different types of PCBs. FR-4 which is used in personal computers has multilayers of fiberglass coated with copper versus double-layered PCBs or single-layered FR-2 PCBs which are used in larger, complex appliances. The FR-2 type has only one layer of fiberglass or paper cellulose or phenolic material that is coated with copper. Firmness is an element that differs across PCBs too. They may be rigid, flexible or have a combined construction. Also, the polymers and other constituent plastics in PCBs may be made from polypropylene, polyethylene, epoxies, and polyesters. PCBs are filled with a smorgasbord of materials.

During recycling, PCBs are usually crushed. Then electrostatic, electrowinning, magnetic, and selective dissolution techniques are applied to separate the components. Non-metallic portions of PCBs primarily contain glass fibers and thermoset resins which cannot be remelted (Sohali, Muniyandi, & Mohamad, 2012).

E-waste (continued)

Sustainable resource management calls for a method to isolate major hazardous components (see Table 5) from the e-waste, and to maximise recovery of valuable materials. Processing scrap metal by itself will curtail mining of ores and significantly save on energy.

Table 5. Hazardous materials in common boating WEEE, adapted from (European Parliament, 2012; Khaliq et al. 2014)

WEEE	Hazardous material
Batteries	Acids & heavy metals such as mercury, lead & cadmium
Switches	Mercury
Computers, TVs	Polychlorinated biphenyl containing capacitors in PCBs
Refrigerators & A/C units	Chlorofluorocarbons (CFCs) & hydrochlorofluorocarbons (HCFCs)
GPS receiver, chartplotter, radio	Flame retardants

In 2020, it was estimated that Australia generated 342 kt of WEEE which is predicted to increase to 461 kt by 2030. Most of this waste is unregulated (Islam & Huda, 2019). A key factor in e-waste management and recycling is to design for resource (DfR) efficiency. By integrating such foresight in design, it will help to mitigate waste when a product arrives at its EOL. Then materials can be retrieved for reprocessing. Careful planning will also help to raise the net intrinsic value of WEEE by maximising the quantity of resources that can be recovered.

Many countries have adopted an EPR scheme that requires producers to take back WEEE (Tanskanen, 2013). Public policy can influence manufacturers to instil DfR in their systems which will push material innovation without hindering functionality of components (Reuter, et al., 2013).

Europe has been proactive in this space, recently unveiling Ecodesign and Energy Labelling Regulations 2021 for 31 product groups (European Commission, n.d.). Manufacturers are now be obligated to offer spare parts for electrical appliances for up to a decade as well as to include repair manuals. Significantly, appliances must be designed to be dismantled, using readily available tools. These ‘right to repair’ policies signal a coming of age in Europe, spurring manufacturers to truly design out e-waste.

08

E-waste (continued)

Australia introduced a national computer and television recycling scheme (NTCRS) back in 2012 which successfully diverts thousands of tonnes of this kind of WEEE. Thirty-one recyclers tend to manually sort and dismantle computers and televisions, but the materials need further processing downstream. Without incentives or mechanisms to do so, the materials generally are exported for this purpose. Australia should invest in infrastructure with pyrometallurgy, hydrometallury, and electrowinning capabilities and institute a WEEE export ban to move beyond this first stage of recycling (Dias, Bernardes, & Huda, 2018).

In short, legislation should be broadened to encompass boating WEEE. It would be ethical and practical to set up WEEE repair centres in the vicinity of GCCM.

09

Timber

Historical evidence demonstrates that deforestation, the second greatest source of greenhouse gas emissions, is mainly attributable to expanding agriculture and forestry trade (Pendrill et al., 2019). It is imperative to stop logging native forests to maintain carbon sinks which are rapidly dwindling. Köhl et al. (2015) carried out a Forest Assessment Report. Their findings show manufactured products from wood were equivalent to 530.5 billion m^3 of timber in 2015, accounting for 20 percent of global carbon emissions. Significant releases of carbon and methane also occurred through deposits of wood waste that anaerobically decomposed in landfill (Shahidul et al., 2018).

Australia does not have recent figures to assess the life cycle of wood, but the U.S. EPA (2021) tracks material specific data from 1960-2018. Data is aggregated from the Center for Forest Products Marketing and Management at Virginia Polytechnic Institute, key industry, and government sources. Calculations of how much wood waste was generated from furniture, packaging, and other durable goods peaked around 2017-2018, hovering at over 18 million tonnes of municipal solid waste (U.S. EPA, 2021). What is remarkable for this period as seen in Table 6 were the spikes in landfilled waste, recording over 12 million tonnes of MSW.

One wood product category that is regularly tossed in the general waste bin is packaging. Pallets are predominant in packaging at 90 percent, but in 2018, only 17.1 percent was being recycled (U.S. EPA, 2021).

Timber (continued)

Table 6. Wood in municipal solid waste by weight (thousands of tonnes), (U.S. EPA, 2021)

Management Pathway	1960	1970	1980	1990	2000	2005	2010	2015	2017	2018
Generation	3,030	3,720	7,010	12,210	13,570	14,790	15,710	16,300	18,200	18,090
Recycled	-	-	-	130	1,370	1,830	2,280	2,660	3,030	3,100
Composted	-	-	-	-	-	-	-	-	-	-
Combustion with Energy Recovery	-	10	150	2,080	2,290	2,270	2,310	2,570	2,880	2,840
Landfilled	3,030	3,710	6,860	10,000	9,910	10,690	11,120	11,070	12,290	12,150

The condition and type of wood waste will dictate how it can be reprocessed (Shahidul et al., 2018). Traditionally wood is reproduced into particleboard or chipped for garden mulching and animal bedding. Since it is a durable material, developments in engineering design enhance the methods to create more value-added products. Research activities have focused on making breakthroughs in three discrete streams: construction and demolition, commercial and industrial waste, and municipal solid waste.

Wood waste recycling is developing for building and manufacturing products as opposed to using it for waste to energy which is controversial (Ramage et al., 2017; UK Government, 2019) due to it yielding higher CO_2 emissions. However, the EU burns a lot of waste to energy in power plants from imported wood pellets that replace fossil fuels such as coal. It can be counted as zero emissions (biomass is a loophole in EU carbon tax counting), but it is neither renewable nor a carbon neutral solution (Reuters Events, 2020).

Findings from a promising study by a team of Columbian, British and Canadian researchers revealed, on the other hand, that greenhouse gas emissions were substantially lowered through recycling construction and demolition waste (Ulubeyli et al., 2017). Conversion to new materials though is relatively new and the technology is costly.

Typically, wood waste is used to make furniture, laminated veneer lumbers, and structural products including floors, doors, stairs, and rafters. After reprocessing, sustainable raw materials can be extracted from wood waste through hydrolysis, pyrolysis, heat treatment, gasification, chipping and pulping (Henriks & Pietersen, 2000). More recently, experiments have been trialled, turning fibers into high-value additives such as indoor acoustic panels or outdoor pavers. Researchers have even tried mixing wood with concrete to achieve elasticity and strength, and a lower weight ratio than concrete (Shahidul et al., 2018).

09 Timber (continued)

Greater input is needed to improve product quality and performance from recycling processes. It has been identified that research is crucial to determine the best compression time, temperature, and pressure for control to process optimal wood waste products (Stelte, 2013). A gap is finding a way to enhance mechanical properties, especially stiffness and strength (Burgett et al., 2002). Certain chemical modification processes have been analysed to improve mechanical properties nevertheless to achieve better resistance to funghi and moisture which could create a sustainable material. Other chemical modification studies of wood waste involved adjusting temperature, and using catalysts, water vapour, organic solvents, and reactive chemicals (Bodirlau et al., 2008). Supply chain disruptions from COVID have led to a spike in demand for used wood which can be exploited for resale at GCCM.

10 Maintenance – fuels, oils, and rags

Maintenance crews at GCCM attend to liquid and solid waste matters both on land and over water in daily operations. Sweep Marine Services (2019) takes care of liquid maintenance by helping customers to unload and refuel fuel and lubricants that could contaminate their boat bilge or surroundings. Oil is toxic to wildlife and detrimental to marine habitats (Australian Government, 2018). Further, the company spends a majority of time cleaning and disposing of black, grey, and residual water. A centrifugal separator machine is used to extract fuel from water when liquids are intermixed. Sweep Marine Services can detect whether any sources of contamination or bacterial growth are present.

There is a liquid storage compound set up for tenants and boat owners to dispose of their own liquid waste as well in bunded areas. There are two 6,000L storage tanks and 12 chemical-grade intermediate bunk containers (IBCs) with a storage capacity greater than 24,000L to collect liquids for storage in sealed containers. Once they reach capacity, the liquids are forwarded to Enviro Waste Services for treatment, to decontaminate them from oil, PCB (polychlorinated biphenyl) and other materials. The Product Stewardship (Oil) Act 2000 (Australian Government, 2020) is a levy-based program that fosters sustainable management of sump oil. Once treated, the oil can be reused as hydraulic oil, industrial burner fuel, incorporated in different products, or re-refined into new lubricating oil.

Whenever waste oil is changed, the dirty filter is concurrently removed. Oil is extracted from the filter for recycling. Waste management companies will collect filters to remove their metal component, but gathering small quantities is not cost-effective. It is also important to separate and remove oily rags for collection. They need to be placed in water and sealed in tins to prevent spontaneous combustion.

10 Maintenance – fuels, oils, and rags (continued)

Cleaning bilges and refinishing tanks through recoating can extend their lives. These services are carried out when potential leaks are identified or to prevent deterioration of engines and hulls due to contaminants, normal high pressure, temperature, and vibrations from running engines. It has lower environmental impact and is cheaper than replacement.

Maintenance staff also take care of solid waste management. The largest waste issues around the shipyard are e-waste and metal tins, timber, tyres, and fiberglass panels. These materials have been discussed elsewhere in this materials analysis section. Presently, they get commingled in general waste skip bins since there are no designated places for them to be recycled or reused. However, a drop off zone is reserved for tyre and battery collection where they are periodically collected for appropriate disposal.

11 Paints, antifouling coatings, and solvents

Oil-based paints are preferred for boats because they have properties including hardness, toughness, and resistance to abrasion, chemicals, and weather. The trade-off, however, is that oil-based paints are manufactured from poisonous chemicals. The primary toxic ingredients in oil-based paints are hydrocarbons, but some paints include dangerous heavy metals as well (e.g., mercury, lead, cobalt, and barium) that are added for pigmentation. While drying, the fumes will linger, depending on the type of paint that is applied. Even though fumes will not cause death, breathing in paints may precipitate dizziness, headaches, and nausea (Poison Control, 2021). Oil paint cures for up to two months, and if swallowed in large quantities, it can be fatal (U.S. National Library of Medicine, 2021).

Solvents are similarly hazardous, but they are a prolific boating product. By virtue of their name, these chemicals effectively dissolve substances. They are employed to thin or strip paints, remove grease to clean machinery and substances left in paintbrushes. Solvents can be more irritating if absorbed through the skin or mouth than oil-based paints, and more lethal if ingested (Poison Control, 2021).

Antifouling coatings are painted on to boat surfaces. They are used to repel or kill algae and other marine organisms that settle and grow on natural and synthetic surfaces which are submerged in marine environments (Costerton et al., 2001). As the organic matter builds, it will alter the strength and solidity of a vessel. Even a millimetre of biofilm can lower boating performance up to an 80 percent decrease in speed due to higher friction. To compensate for this loss, boats burn more fuel, hence, increasing emissions (Hakim et al., 2011). Boat owners consequently are forced to frequently clean their hulls which increases their maintenance costs.

Paints, antifouling coatings, and solvents (continued)

Since the 1960s, manufacturers introduced slow-release antifouling coatings that were strikingly effective at targeting the worst fouling agents, and their usage surged between 1988 to 1993, Notwithstanding the input of these higher concentration levels of biocides on boats, ecosystems in marinas were not monitored for corresponding safety risks (Voulvoulis et al., 1999). The Pesticides Safety Directorate documented 600 different antifouling mixtures contained 60 active ingredients in 1998 (Wells, 1998). Substances consisted of organotin and copper antifoulants alongside booster compounds which broaden the power of these reagents (Cima & Varello, 2020), and are highly likely to lead to widespread toxicity.

Newer eco-friendly compounds have been formulated albeit they are less effective than traditional biocides. Certain substances have been banned as stated, TBT or TPT (Voulvoulis et al., 1999), but regulations vary on what is approved content in antifouling paints across global regions. In the EU, for example, the Biocidal Products Regulation (BPR) authorises usage of the popular ingredient, cuprous oxide. They suggest the minimum amount should be whatever is necessary to get the desired effect of the antifoulant which is ambiguous.

Researchers (Lagerström et al., 2020) studied the effects of the release rate of the commonly used biocide, cuprous oxide, in four different harbours. They measured the effects on panels that were coated with this antifoulant through static exposure. Salinity in the harbours ranged from 0 to 27 PSU (Practical Salinity Unit). They found copper leached higher where salinity increased. Significantly, there was no difference in product efficacy at all locations. Findings imply cuprous oxide types of antifouling products with four to six times lower release rates are equally efficient as those products with higher release rates. Further, it is unnecessary to apply this product in freshwater to cause harm to the environment or people because it has no effect in freshwater.

Substitutes have emerged with vinyl-wrap coverings that rely on their slippery surface to repel aquatic organisms. These wraps are available at GCCM. They can be peeled off at their EOL, but it is hard to recycle the film or its coated paper backing. High-tech solutions have been invented that rival traditional coatings using silicone, Teflon, coatings that use nanotechnology (for high-end racing boats) or a synthetic fluoropolymer, polytetrafluoroethylene which has non-stick properties. There are no conclusive results to date on fluoropolymer toxicity (Sajid & Ilyas, 2017).

11 Paints, antifouling coatings, and solvents (continued)

Due to the toxic nature of paints, antifouling coatings, and solvents, they cannot be reused. If disposed of improperly, these products can contaminate waterways. If put in landfills, they can seep through the soil to contaminate the underground water table. If not stored properly, solvents can be flammable, and again, are dangerous to people (Lagerström et al., 2020). Findings from the cuprous oxide study are important in realising that these biocides and other chemical agents can be substantially reduced to minimise negative effects. It is critical to influence governments to mandate stricter policies, either to cut back or eliminate the harshest substances through passage of more international treaties.

The Australian Government has at least stepped in to offer a take-back program, the Paintback Scheme (2021), whereby painters can dispose of up to 100 litres of water-based paint. It is free of charge and collection points are available in the Gold Coast region. This industry-led initiative is national. Authorised depots accept deck coatings and floor paints, interior and exterior architectural paint, packaging, primers, sealers, stains and shellacs, undercoats, varnishes and single-component urethanes and wood coatings. Funding of this program helps to subsidise sustainable research such as recycling unwanted plastic packaging.

12 Rubber

In 2018-19, 465 kt of tyres reached their EOL in Australia (Schandl et al., 2020), but no domestic manufacturing facilities exist, so they are all imported. Unfortunately, only 14 percent are turned around for domestic recycling and conversion through energy to waste. 55 percent of tyres are exported at EOL, and the rest is sent to landfill. However, the Federal Government will be banning the export of unprocessed tyres.

Recycling processes include shredding, crumbing, granulating, buffing, retreading, and using tyres in civil engineering projects. Recycling rates should be bolstered to reduce mining new resources. It uses less energy than production of virgin materials, and it prevents hazardous emissions of air pollutants (U.S. EPA, 2021).

Regulations have been imposed overseas concerning the processing of rubber, using cements, solvents, and associated mixtures during production of tyres and cords, and the application of puncture sealant.

12

Rubber (continued)

Tyres may be derived from rubber or synthetic materials, and their respective proportions will depend on the type of tyre that is being manufactured. Considerations include what is the end use for a particular tyre and what kind of environmental conditions does a particular tyre need to be driven in (Bockstal et al., 2019). For instance, a tyre might have to be designed to withstand extreme temperatures or rugged road terrain.

If so, then carbon black rubber gives mechanical support and acts as a shield for abrasion. Metals also reinforce toughness. They are ideal to manufacture truck tyres whereas lighter tyres blend rubber with textiles (nylon, rayon, and polyester). Other components are added for vulcanisation. Global tyre demand has surged to approximately 3 billion units by 2019 (Bockstal et al., 2019). Growth is largest in places where motorisation is strongest. Australia has a high rate at 182 cars per 1,000 inhabitants (OICA, 2019).

Multiple challenges hinder repurposing of used tyres in this country when they reach EOL. For starters, the Australian tyre stewardship scheme is a voluntary rather than mandatory program. Policies and disposal fees are inconsistent, giving consumers mixed messages. This is exemplified by the lack of quality standards on imported tyres, and levies are issued on some types of tyres but not others.

Competition in domestic markets is stifled by subsidies on imported tyres. Consequently, supply chains operate across vast distances which are disconnected. It is difficult to track safety and sustainability records of suppliers because they are not audited. Many manufacturers follow different standards to produce tyres using different specifications (Schandl et al., 2020).

Nonetheless, key opportunities are available for repurposing tyres. First, it is best to avoid tyre usage by replacing one’s mode of transport with lighter ways to travel such as walking, taking public transit, or carpooling. Second, tyres should be redesigned to use less materials, be longer-lasting, and be capable of remanufacture. Third, technology should be integrated that can keep track of the chain of custody for tyre purchase and consumption. Then it would be easier to build a system for reverse logistics, to collect tyres for reprocessing. Fourth, companies should be capable of retreading and remanufacturing used tyres. Fifth, deeper engagement in other forms of recycling like energy recovery through mechanical and thermochemical processing is called for. Sixth, tyre-derived recyclates should be extended for use across civil engineering projects, including sealing and resurfacing, and as a component in moulded products. Alternatively, recyclates can become a composite in manufacturing products such as cement, or be converted to oil, syngas, and steam for producing energy (Schandl et al., 2020).

12

Rubber (continued)

Green Distillation Technologies Corporation Ltd. (2021) built a Victorian plant to create oil, steel, and carbon from used tyres. This pilot plant opened in 2015. It has achieved breakthroughs by recovering energy from tyres. The corporation will expand its capacity after receiving a permit from the NSW EPA for another processing module in Western New South Wales.

Each state and territory in Australia have a different set of conditions to recover tyres that are contingent upon regulations, consumer demand, distance to an international port, and density of the population (Genever et al., 2017). Queensland and South Australia show the highest share of domestic recycling at 19 percent followed by Victoria at 15 percent, Tasmania at 14 percent, New South Wales at 12 percent, Northern Territory at 8 percent, Australian Capital Territory at 5 percent, and Western Australia at 4 percent (Randall et al., 2020).

Tyres are illegally dumped in the shipyard. GCCM needs to keep tyres out of general waste skip bins to prevent contamination and find a local reprocessor for this rubber waste.

Waste mitigation action plan

Roadmap for waste stewardship

1 yr › 5 yrs › 25 yrs

Short-term interventions: 2021-2022

There are many short-term commitments and actions that can be undertaken for improved environmental outcomes coupled with marketing to drive increased business for tenants and the Marina. The activities and benchmarks have been determined by the ease of implementation, and lowest to highest costs and benefits that are expected over time. At a minimum, licensed environmental authority conditions of approval given in appendix 1 should be reinforced at all workplaces.

A site inspection at GCCM revealed there are still many cans and bottles and particles of dust in the general waste bins which can be diverted from landfill and will alleviate contamination of waste. If staff members become proactive, it will boost the success of initiatives. Providing education and training for recycling awareness is critical to create a marked difference in recycling and recovery rates. Savings must be documented and communicated so everyone can take pride in their efforts to spur greater change, and it will strengthen the brand image for all businesses at the Marina.

Another significant activity to be expedited at GCCM is to get tenants to participate in the ASPIRE program. This online trading marketplace will enable recirculation of e-waste and other materials. Shaikh, Thomas, & Zuhair (2020) identified consumer willingness to pay for e-waste if a collection and recycling system is made available, and GCCM has subscribed to this program.

To pay for initiatives, an environmental fund can be initially established with tenants and customers on a donation basis to build momentum for waste management. A waste fee can later be introduced to launch activities that require more substantial funding.

Short-term interventions (1 - 6 months)

Short-term tactics for waste management and resource recovery that should be demonstrated within a year are in Table 8. Some activities call for participation by internal actors at GCCM while others need outside players from industry, government, research, and the community. Projected costs are inserted for known items such as purchasing source separation bins for offices. Grants and funding will be sought whenever it is feasible to apply.

Table 8. Proposed tactics

Activity	Actors - Internal/External	Benefits	Barriers
0 - 3 months			
Target key on-site businesses and stakeholders to attend a co-design workshop to assist with building the framework of the resource recovery project	Internal & External	Obtain buy-in and engagement from key stakeholders internal & external to GCCM Identify key resource recovery priorities, challenges, and opportunities	Lack of data relating to all site waste volumes and types Lack of understanding of available recycling and resource recovery options on site
Audit tonnes of waste at all businesses	Internal	Determine accurate volumes & types of waste materials for improvements	Small amount of time & effort to log amount in waste register for one month (sample in appendix 2)
3 - 6 months			
Resource Recovery Workshop – educational session with on-site businesses to review recycling options & resource recovery strategy Launch 'Closing the Loop on Waste' & GCCM charter with on-site businesses	Internal & External	Raise awareness and understanding of waste types, recycling options, valuable resources for reuse/ recycle/ remanufacture Gain commitment and buy-in from on-site businesses to drive resource recovery outcomes	Time for periodic attendance
Heighten source separation by tenants, staff, patrons & the public in appropriate disposal bins; add recycling bins on site with clearer signage displayed & increase information for arriving customers in welcome guides	Internal & External	Raise recycling rates & reduce contamination of larger waste streams	Resistance to change & upfront costs of $130 per 60L Ecobin & $349 for 466L Earthmaker composter
Integrate ASPIRE platform across on-site businesses to increase resource recovery of various marine resources & materials	Internal & External	Increase revenue for waste products instead of adding to pollution & levies	Time to become familiar with this system – membership cost absorbed by Gold Coast City Council for GCCM
Work with Queensland Government & Gold Coast City Council to source additional resources & leverage key contacts to increase resource recovery options & partnerships	Internal & External	Solve waste issues for a cleaner, healthier environment & stimulate job growth in region	Design collaborative pathways for change
Develop a PR plan & commence regular communication of the program in newsletters & media to increase awareness & project partnerships	Internal & External	Gather momentum for waste recovery as an asset	N/A

Table 8. Proposed tactics (continued)

Activity	Actors - Internal/External	Benefits	Barriers
6 - 12 months			
Training videos of correct waste procedures will be created & uploaded on the GCCM website to relay to all staff & customers	Internal & External	Amplify efforts of the program	Instil new habits - $1,000 per video
Educational seminars to be scheduled for tenant meetings to brief business owners on solid & liquid waste issues	Internal	Network to fulfil like-minded objectives of waste reduction & repurposing	N/A – Speakers will be complimentary
Plastics – source sustainable substitutes for all unnecessary single-use items	Internal & External	Less plastics in ground & waterways to disturb biodiversity	Search & procure sustainable substitutes
Textiles & carpets – send uncoated remnants for reuse or donation, request for coated fabrics to be taken back by manufacturers & replace carpets with carpet tiles by Interface Carpets	Internal	Find new owners willing to pick up offcuts, or donate for stuffing in bedding, or give to charities for rags or arts & crafts outlets	Lack of accountability by manufacturers for their products post-consumption
Glass, e-waste, wood, printer cartridges & other types of packaging materials to be segregated from other mainstream recycling with a purpose-built collection station & then sent for resale or repurposing through ASPIRE or elsewhere, preferably in Southeast Queensland – branding of the marketplace to be posted around the site	Internal	Diversify the kinds of waste for new end-of-life (EOL) options	Drop off items in new recycling station to be set up near the entry/exit gate at GCCM – donation to Men's Shed for building the station
Organics – set up a composting facility to gather all food scraps & instal vertical gardens for regenerative agriculture that can be used by the food outlets	Internal	Close the loop on food waste	Small amount of time & effort – depending on the composting system, omit certain food scraps that can clog machines – a small vertical garden costs $2,200
Hazardous waste – make sure all liquids & solids are contained & being disposed of properly	Internal	Prevent catastrophic leakages	Extra care & attention
Collect empty oil drums for return & reuse by suppliers	Internal & External	Stop unnecessary manufacture of new oil drums	Hold manufacturers accountable for their products at EOL

Mid-term interventions: 2021-2026

Below is a list in Table 9 of longer-term activities that have been identified to obtain the goals and continue to build the reputation of GCCM within five years. The rationale is to keep moving forward with prevention, removal, research, response, coordination, and monitoring and detection for better handling of material streams while overcoming financial, social, institutional, and technical challenges that demand regulatory change. Designing out planned obsolescence through passage of right to repair and extended producer responsibility legislation is essential to speed progress and exhibit leadership.

Table 9. Proposed tactics

Activity	Actors - Internal/External	Benefits	Barriers
Cotton & polyester – divert these textiles for break down into substrates capable of remanufacture at Blocktexx	Internal & External	Close the loop on certain textile waste	Small amount of time & effort to coordinate logistics to Logan
Solicit an Australian paper manufacturer to recover boating wrap for remanufacture	Internal & External	Eliminate tonnes of waste in the backing of adhesive film	Lack of interest by a paper manufacturer to undertake this venture
3D printing of waste products, e.g., benches and planters or boat bumpers filled with mycelium	Internal & External	Close the loop on waste by avoiding polystyrene with creation of added value products	N/A - in-kind funding by QUT to engage in R&D for commercialisation of new products
Materials database – review boating suppliers' stock & alter offerings with more sustainable products	Internal & External	Change a portion of supplies to reduce toxic chemicals or pollutants	Time for review & to locate better alternatives & effort to changeover
Install Seabins at all berths in the Marina	Internal	Skim water pollution from the Coomera River adjacent to GCCM	Funding to procure many Seabins at \$5,000 per bin & to allocate staff time for changing filters that fill with debris
Educational seminars to be scheduled for tenant meetings to brief business owners on solid & liquid waste issues	Internal	Network to fulfil like-minded objectives of waste reduction & repurposing	N/A
Training videos of correct waste procedures will be created & uploaded on the GCCM website to relay to all staff & customers	Internal & External	Amplify efforts of the program	Instil new habits
Continue to administer PR plan with regular communication of the program in newsletters & media Install QR codes & relabel recycling bins with updated & clearer Australian labels	Internal & External	Gather momentum for waste recovery as an asset	N/A

Ongoing interventions: 2021-2046

The following tactics in Table 10 are intended to attain the highest level of environmental enhancement for health and wellbeing. These activities align with strategies in the Sustainable Development Goals (SDGs).

Table 10. Proposed tactics

Activity	Actors - Internal/External	Benefits	Barriers
Publish environmental guidelines on the GCCM website for all tenants & customers	Internal	Widespread transmission of sustainable action	N/A
Promote environmental accreditation programs to tenants	Internal & External	More entrenched activities by on site businesses	Time and effort to undergo management programs – costs TBD by each certification provider
Seed businesses for remanufacturing of difficult materials, e.g., turning fiberglass laminate into sailing boats or other global initiatives discussed under findings	Internal & External	Find uses for scrap that is a problem & continues to accumulate	Investment in infrastructure & ability to make viable enterprises
Offer renewables for boats with solar & hydrogen-powered boats with available refilling stations for fuel cells	Internal & External	Cleaner powered boats	Competition from traditional sellers & servicing of particularly diesel-powered boats
Educational seminars to be scheduled for tenant meetings to brief business owners on solid & liquid waste issues	Internal	Network to fulfil like-minded objectives of waste reduction & repurposing	N/A
Training videos of correct waste procedures will be created & uploaded on the GCCM website to relay to all staff & customers	Internal & External	Amplify efforts of the program	Instil new habits
Continue to administer PR plan with regular communication of the program in newsletters & media Issue a sustainability report to be issued to give a synopsis of the impacts from the waste program	Internal & External	Gather momentum for waste recovery as an asset	N/A

Impact measurement

There are multiple avenues for tracking and monitoring progress to meet the goals of a project. A theory of change approach (Weiss, 1995) lends a framework to encourage participation of staff and other stakeholders illustrating how and why change is expected. In this context, boating waste requires remediation. The goals have been defined, and preconditions for success have been identified to deliver on the outcomes. The following data will be accumulated and reported to GCCM's network of stakeholders to evaluate how the program activities are delivering discrete improvements at different points of time to show outputs, and then outcomes and impacts.

Key measurements

- Diverted from landfill – tonnes of waste
- Resources exchanged – quantitative results of diversion from landfill
- Revenue generated - assessment for transparency
- Emissions saved – tonnes of CO_2

"When people realise the direct cost of their waste…and the potential of recycling it, behaviours change."

Ron Gonen, author of *The Waste-Free World*

KPIs to work towards SDGs

GCCM should remain dedicated to championing change in the wider boating industry. As a role model, the Marina wants to empower colleagues and citizens to embrace their own methods to reduce and repurpose their waste. It will only be possible to achieve net zero goals for sustainable development if everyone gets on board and spreads a lighter waste footprint.

GCCM has set the following targets and indicators in Table 11 to account for its contribution to the UN Sustainable Development Goals to preserve the public and patrons within its pristine marine environment.

Table 11. Proposed tactics

SDGs	Targets	Indicators
SDG #12 – Responsible Production & Consumption	Ensure that people have relevant information and awareness for sustainable development and lifestyles in harmony with nature.	Take surveys to measure the extent to which education for sustainable development is mainstreamed through education of staff and patrons.
SDG #13 – Climate Action	Improve institutional capacity on climate change mitigation and adaptation.	Get existing or new tenants as renewable energy providers for boating.
SDG #3 – Good Health & Wellbeing	Reduce the number of illnesses from hazardous chemicals and air, water, and soil pollution and contamination.	Lower sick days by staff.
SDG #11 – Sustainable Cities & Communities	Share in the waste management reductions impacting the surrounding city.	Host sustainable events for families on Sundays.
SDG #14 – Life below Water	Prevent and significantly reduce marine pollution of all kinds, particularly from land-based activities, including marine debris and nutrient pollution.	Chart the reductions from Seabin filters and release ratings on local water quality.
SDG #15 - Life on Land	Take urgent and significant action to reduce degradation of natural habitats.	Plant trees in the current and future site.
SDG #17 – Partnerships for the Goals	Enhance global partnerships for sustainable development, complemented by multi-stakeholder local partnerships that mobilise and share knowledge, expertise, technology, and financial resources,	Hold industry boating conferences to exchange information on learnings & best practices in waste management.

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Appendices

A. Sections of City of Gold Coast Environmental Authority concerning waste management

1. Waste – disposal

   A contaminant (including a waste) must not:

   a. Be buried at the premises; or be in contact with soil at the premises; or directly or indirectly seep or penetrate into the soil or groundwater at the premises

2. Regulated waste – storage

   Regulated waste must be identified and segregated from non-compatible waste streams for storage and collection by an approved waste transporter.

3. Regulated waste – removal

   Where regulated waste is removed from the place (other than by a release as permitted under this environmental authority), the operator must monitor and record the following:

   a. The date, quantity and type of waste removed; and name of the waste transporter and/or disposal operator that removed the waste; and the intended treatment/disposal destination of the waste.

4. Waste and recycling storage facilities

   Waste and recycling storage facilities must be provided in accordance with the following provisions:

   a. Adequate waste containers must be constructed of a solid concrete base or acceptable equivalent; and the permanent waste storage point must be designed and constructed so it can be easily cleaned whilst ensuring that no waste or recyclable matter is released to the stormwater system or any waterway.

5. Waste container cleaning

   Maintenance and cleaning of waste containers must be carried out by an approved contractor and in an area where contaminants cannot be released into storm water drainage, a roadside gutter, or onto unsealed ground.

6. Waste storage – maintenance

   All reasonable and predictable measures must be taken to ensure the waste storage area is kept to a standard of cleanliness where there is no accumulation of:

   a. Waste, except in waste containers; recycled matter, except in containers; grease, or other visible matter

B. Waste Register

GCCM tenant____

Start date______________________ Finish date____________________

Waste category	**Waste Type**	**Amount of waste disposed (kg, m^2 or quantity)**	**Waste disposal method (e.g., general waste bin, delivery to waste transfer station, or elsewhere)**
Plastic waste	Plastic wrap		
Metal waste	Stainless stanchions		
Chemical waste	Epoxy		
Physical waste	Interior carpets		
Hazardous waste	Asbestos containing cables		
Chemical waste	Antifoul		
Physical waste	Paint tins		
Hazardous waste	Batteries		
Chemical waste	Bilge water / degreaser		
Other			