RECYCLING BIKES: BIKE PARTS PRODUCTS AND INNOVATIONS

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Overview

Bikes are one of the world's most popular and oldest modes of transportation, with 800 million bikes worldwide, outnumbering cars by two to one (Paul Lee, 2020). Technological innovations and the spread of bike sharing platforms are making bike riding more attractive to millions of commuters. This increase in popularity brings with it sustainable practices, traffic avoidance, health benefits and to cities worldwide. With recognition further been increased due to its capacity as a covid safe means of transportation. In total Deloitte, predicts a 1 percentage point rise in the proportion of people who bike to work during the three years from 2019 to 2022 (Paul Lee, 2020).

Trends

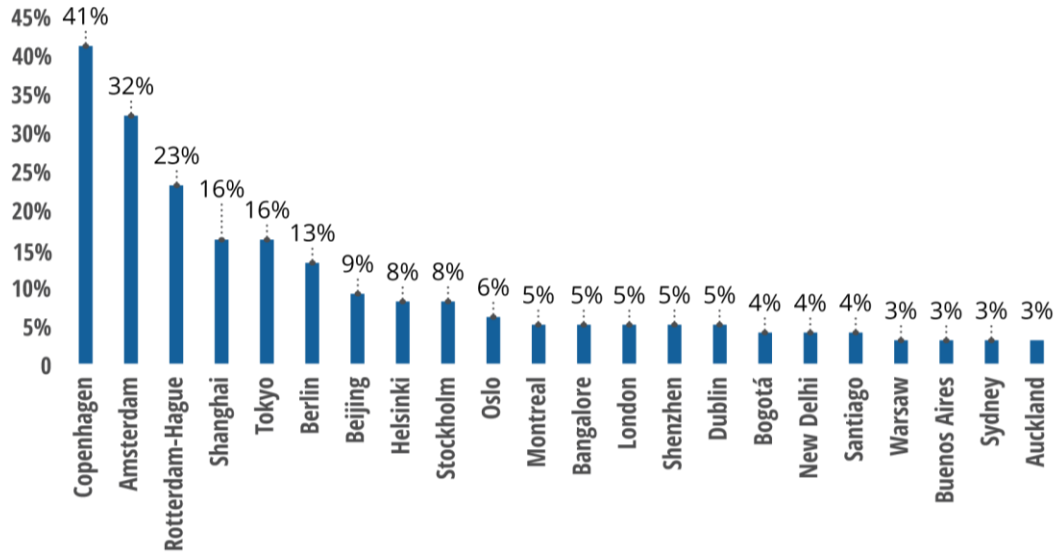

Figure 1: Percentage of Journeys taken by bike 2019 (Paul Lee, 2020)

This increase focus and use of both bikes and e-transport options, brings to light the need for appropriate recycling methods, particularly when we acknowledge the growing focus on climate-sensitive and conscious choices.

Current Recycling Industry

To date, governments have had very little intervention with recycling bikes schemes and more so focused on promoting bike use and providing appropriate facilities needed like, parking, bike sharing systems and bike lanes. Instead, the recycling industry of bikes has been propped up by not-for-profits and small organisation trying to reduce waste within the industry. While they have made massive steps forward, widespread location and access is a problem, particularly when it is predicted that within the next two years, the number of bikes that have been destroyed and need to be scrapped will increase rapidly, causing serious environmental damage (Aijun Liu, 2019). Because of

the widely accepted belief that bikes are the most sustainable form of transportation available today, cities everywhere are promoting programs to increase bike use. However, the raw materials involved in the production process and upkeep impact our environment.

- Today most bike frames and wheels are made from aluminium alloy, meaning that the metal has traces of silicon, iron, copper, manganese, magnesium, chromium, zinc, and titanium, but is mainly composed of aluminium (Juliana Luna, 2016).
- Tiers are made from rubber mixes which vary, depending on the style of bike being produced. Most however, are produced from butyl rubber which is made by polymerization of about 98% of isobutylene with about 2% of isoprene (Lakin, 2018).
- Bike chains are made from steel, which is produced by combining coke, iron, and small amounts of limestone.

The consumption continues when owners make repairs to maintain the bike's condition. The most common two bike repairs are replacing a tire and replacing a chain. As a result, more synthetic rubber, natural rubber, and steel are used for bicycle maintenance.

At the end of a bike's life, it can either end up in a landfill or its components can be recycled saving large amounts of energy. The large amount of aluminium within bike parts can be recycled, as pure aluminium can simply be melted down to form new products for their next life (Juliana Luna, 2016). Aluminium is also infinitely recyclable and can save as much as 95% of the production energy making recycling in any form of great value (Waste and Resource Recovery Resource Recovery Unit, 2012). Although steel is not quite as efficient, the recycling of steel can save up to 74% in primary production energy, and the recycling of Stainless Steel can save 67% of primary production energy (Worldsteel Association, 2021). Rubber tires are also very recyclable, with 2nd life possibilities such as rubberized asphalts tire-derived fuels, purses, and shoes (Juliana Luna, 2016). Recycling can greatly reduce the amount of raw materials that need to be extracted and the extra production energy that goes into making the product from raw materials.

Figure 2: Bike Life Cycle (Juliana Luna, 2016)

Current Organisations

Currently the potential for bike recycling has huge capacity to be ingrained within a circular system, however it has solely been reliant on industry projects that have taken initiatives. Bikes are growing in demand and that along with consumption and production impacts, makes recycling bike parts an increasingly needed resource. Here are several organisations recycling bikes in some form or another.

ORGANISATIONS RECYCLING BIKES/ PARTS		
WHERE	**WHO**	**HOW**
Budapest Hungary	Felvarrom	They collect worn out bicycle parts to handsewn apparel from the recycled bike tubes and tyres, sorting and cleaning the used parts one-by-one, pick which ones are lucky enough to reborn as a belt, a wallet or a toiletry bag. Remaining materials are also dealt with eco-consciously, transported selectively for the local recycling facility. production is a bit different. The raw material arrives from friends, shops, then we go through them, clean them, cut and store them. From then we only touch the ones that are going to become a product, if they aren't good enough for us, then it goes to the local recycling centre. Sells products on a range of online websites
USA, Providence	Recycle-A-Bike is a Providence non-profit	They recycles bicycles for the local community. They save roughly 600 bikes a year from ending up in landfills. Recycle-A-Bike empowers the local community by holding classes on how to fix and repair their own bikes using donated and recycled bike parts. The recycled bikes are also donated to local charities in need. For example, Recycle-A-Bike recently donated bikes to the Dorcas International Institute of Rhode Island, which needed to provide a reliable method of transport to refugees.
Victoria Australia	Recycle Bike Tyres	provides participating bike shops with a wooden crate, that he custom builds from recycled timber to a size that fit's each shop's designated space. He'll typically visit each bike shop to collect their tyres every four to six weeks.

		Charlie also provides retailers with a brochure to show staff and customers how the system works and stickers with QR codes. Charges retailers $2 per tyre and 50 cents per tube that they recycle. As they are then sent to Tyrecycle which charges a fee.
Durango, Colorado	Velorim	Velorim has been set up to manage the collection and recycling of inner tubes and tyres on a national basis. You simply need to take your tyres and tubes to your local Velorim Centre where, for a small contribution, they will be disposed of ecologically.
	Krizevac	Krizevac Project creates self-sustaining businesses to provide lasting income which is then used to help the poorest of the poor. Saving bikes from landfill when they are decommissioned
	Cycle of Good	Take old tyres and tubes and created new products. And save bikes from landfill by stripping the frames. They work with prisons to help youth inmates develop employment skills and gain certificates in bicycle maintenance.
UK, Netherlands and Germany	Schwalbe	They produce high-quality, durable products with long service lives. Their approach is a sustainable product design from cradle to grave. They have not reached their goal yet but are on track. They supporting this recovery process with a procedure which is both free of charge and easy to use for every bike retailer, and also for cyclists.
USA	Maxxis	Produces green tyres
Europe	Continental	In Europe Continental is already one of the leading tire manufacturers in both the original equipment sector and the replacement business.
Australia, Canada and USA	1800-GOT-JUNK? Bicycle disposal	1800-GOT-JUNK? Specializes in bicycle recycling. Whether you are looking to donate bicycle parts near you or need to dispose of an old bike, we are here to help! We will pick up your old bicycle from anywhere on your property. Depending on its condition, they will either recycle your bicycle at a local bike recycling facility or donate it to someone in need.
Amsterdam	Bikes4life	Bikes 4 Life is a not-for-profit organisation that alleviates poverty and social injustice in Australia and overseas by recycling and restoring discarded bikes.
UK	Bicycle Charity	They accepts used bikes and sends them to four partner organizations in Africa, in four different countries, which repair, distribute and maintain them. It also sends spare parts and tools for free, which are sold there (as are the bikes) at a fraction of market value.
London	Bikeworks	They upcycle bikes for sale, fix bikes, provide cycle lessons and provide workshops to help individuals become cycle mechanics. It is run by disadvantaged individuals
Sydney	Bike Love Corral	Bike Love Corral, located at the University of Newcastle and accessible to both students and non-students, provides a free recycling service for bicycles and parts/accessories **in all conditions**. They also offer bike fixing services.
UK	Yesrecycling	The National Hard Hat Recycling Scheme aims to change that by diverting hard hats into a dedicated waste processing facility, thereby ensuring all hat waste is fully recycled. The scheme is a membership scheme, whereby registered members can send their hard hats directly into a dedicated hard hat recycling facility where they will be destroyed, with all of the plastic being fully recovered and made back into “new” plastic pellets.

Although bike parts can be recycled into numerous innovative new products, they are also being recycled into brand new bikes that have an endless range of potential. Each of these companies are maintaining an increased need within the recycling and bike industry alike. It is also bringing with it work experience, skills and affordable transportation for local communities. The key materials used to make bikes – aluminium, steel and rubber – are all recyclable, yet numerous unwanted bikes are still ending up in landfill, wasting precious resources.

Plastic Bikes

Much like the promotion of recycling bikes, various recycled plastic bikes have been produced around the world. Millions of tons of plastic are consumed annually in the world due to its significant characteristics such as durability, flexibility, and low weight. High consumption has made plastic one of the most important municipal solid waste compounds, the quantity of which has increased in recent decades (Javad Torkashvand, 2021). With proper attention, the bike recycling industry can be taken to the next level of innovation and environmental protection. Inventors all over the planet are starting to make bikes from recycled materials, cutting out pollution and raw material usage in the manufacturing stage, yet again reducing the carbon footprint, and providing and even more earth-friendly means of cycling. Using recycled plastic is now a great solution that is affordable and practical.

WHO	*WHAT THEY ARE DOING*
AO Bike	Designed by Omer Sagiv, the AO Plastic Bike has a frame made entirely of, yep you guessed it, plastic. That plastic, however, happens to be 100% recycled, which hugely cuts down on the retail cost of the bike. Other notable features include a single gear system as well as dynamo-powered lighting.
Frii Bikes	A bike made from recycled plastic and was designed by Israeli industrial design student, Dror Peleg. The bikes are also created by using recycling machinery to inject melted plastic into a mold. All parts are made from plastic and are strong and durable.
The EADS Airbike is a bicycle constructed from laser-formed nylon powder and made by EADS	The FRII Injection molding recycled plastic bicycles is a rather new design, from 2011. It is to be made entirely from injection-moulded recycled plastic. The chair set can be pulled out and replaced to adjust to the height of the rider. It is to be produced by local industries for economy and ecological reasons, as its manufacture process is simple and low cost in large quantities.
Muzzicycles developed a patented process to make bicycle frames with recycled plastic using injection moulding.	They can currently recycle 15,000 tons of plastic, primarily bottles, with which they can make 132,000 bicycle frames. Using recycled plastic saves 980 tons of oil and reduces greenhouse gas emissions by about 6,000 tons of CO2.
The Dutch start-up Dutchfiets, created a bicycle made from recyclable plastic.	The frame and wheels of the bike are 100% made out of recyclable plastic. Even the production of the plastic is energy-efficient. The aim is to eventually use bio-plastics in the future to make the bicycle even more sustainable. You can also bring back the bike at the endo of its life cycle to DutchFiets so it can be recycled again.

These recycled plastic bikes are innovative niches that allow us to make something useful out of someone else's waste. Plastic is a reusable and recyclable material. So, with a change in perspective on waste, new avenues can reduce waste and optimise the recycling of the bike industry.

However, according to the organisation in many cases tyres are not suitable for reuse (being too worn or damaged, or of unconventional sizes) so the problem of tyre waste is simply moved from the retailer to the charity. While this option, and other similar bicycle refurbishment projects, provide another opportunity for retailers to avoid sending bicycle tyres to landfill, in practice only a very limited number of tyres can be included in this method. (Watkins, 2014)

Australia is home to the leading tyre recycler globally, Tyrecycle. Because recycling tyres is an industry scale process, they only take large scale deposits. Tyrecycle can turning tyres and tubes into crumbs that can be used for a wide range of recycled products ranging from playground and athletic track surfaces through to building insulation (Tyrecycle, 2021). As national use of bicycles for both transport and leisure purposes has increased, consumable bicycle components such as tyres, inner tubes, chains, and gear cassettes must also have increased. Traditional commercial waste materials generated by the cycle trade (cardboard, paper, plastics) can be widely recycled (WRAP, Undated) and are included in many trade recycling collections (Biffa, 2011; Grundon 2011). Metal wastes can also be widely recycled as the market and value of metals are well understood (BMRA, 2010). The problem of waste tyres is a significant issue for the bicycle retail trade. When customers purchase new tyres most bicycle shops will fit them. In many cases, particularly where old tyres are too worn for future use, or are damaged, the shop is left the problem of disposal of these old tyres. The problem consists of two elements. Firstly, tyres cannot be recycled as facilities seem to be non-existent, or costs of disposal are too high. Secondly, some retailers have found that tyres cannot be disposed of at all (through recycling or as general waste to landfill through traditional contracts).

Bike Sharing

The sharing economy represents a new business model in which the access to goods, services, spaces, and other assets can be shared or obtained. Bikes and Scooters alike are now playing a major role in the sharing economy, as it has been able to achieve global levels of success at an unprecedented space (Xiaodong Lai, 2020). More than 1,000 dock-based bike sharing programs exist worldwide,42 representing tens of millions of shareable bikes (Paul Lee, 2020). Public transportation is an important participant in sustainable energy and the shared economy plays a key role in reusing what we have. However, Bike-sharing is meant to be an environmentally friendly practice, yet mass production and insufficient recycling of shared bikes may bring great negative environmental impact (Guozhu Mao, 2021). Both production and maintenance play key roles in the life cycle of shared bikes and intern the wasted caused. Due to the high daily usage and lack of effective maintenance, the number of bikes in good condition decreases significantly, and vast piles of broken bikes appear in many big cities (Cong Zhang, 2019). Working time limitations, vehicle capacity constraints and broken sharing bike recovery benefits are all influencing their capacity to be recycled. The randomness of use and the wide range of services provide enormous challenges in the operation and maintenance of these bikes (Lu, Zhang, Su, Gao, & Luo, 2019). This is particularly critical as the share bike industry has major issues with dumping, destruction and limited upkeep that is creating huge waste piles going to landfill (Chardon, 2019). There is the potential for an organisation to use recycled parts to fix these bikes, using a multi-step collection solution, so they are maintained or potentially purchased and fixed at a lower cost before the bike is to damage to be fixed.

E-Bikes

Sales of electrically-assisted bikes (e-bikes), have been rising in many European countries. Due to their electrical assistance, e-bikes could increase the number of people cycling and the potential uses of cycling. Sales of e- bikes have been growing in the last ten years, with e-bikes representing more than a third of all bicycles sold in Switzerland in 2019 and up to half in the Netherlands (Dimitri Marincek, 2020). E-bikes have been shown to provide health benefits and are now a fundamental

influence in bike cultures around the world. It opens new forms of transportation to many who might have otherwise hesitated before.

Batteries

Generally bikes are built to last a lifetime, but the batteries slowly deteriorate over time, and typically run out of power after four and six years (Silvia Baeva, 2019). Recent improvements in lithium-ion battery (LIB) technology, pricing, and power, has increased the e-bike market interest, particularly for high-end models. Between 2020 and 2023, more than 130 million e-bikes are expected to be sold (Paul Lee, 2020). E-bikes and e-scooter recycling methods are particularly important as they are being sold at high rates of increase around the world and intern increase usage. E-transport has the potential to displace conventional motorised modes of transport in urban areas, with the potential to displacing traditional bikes (Elliot Fishman, 2015). The current levels of lithium battery collection in Europe are very low with only an estimated 5 per cent of batteries on the market being recycled, most are incinerated or end up in landfill (Smurthwaite, 2018). Modern technology requires modern solutions and so issues like the recycling of e-bike batteries are now a priority in the bike and waste industries.

Organisations recycling Bike batteries

Call2Recycle manages an elaborate network of battery collection sites to get batteries out of the market and to the right processor. They will be packed in UN-certified fire-retardant boxes and shipped per Transport Canada guidelines.

Direct recycling starts with dismantling and shredding of the cells and recovery of copper and aluminium. The goal is to retain the cathode crystal morphology to remake a new cathode.

Hydrometallurgy also starts with dismantling and shredding of the cells and recovery of copper and aluminium. The remaining black mass of metals goes through a leaching process that separates each metal and returns them to the original state with a 95% recovery rate.

Pyrometallurgy feeds battery packs and/or modules into a furnace and sends the copper to a mixed alloy product, and the aluminium and lithium to slag. The use of an electric arc furnace will result in most of the lithium turned to a dust-like powder, from which it can easily be recovered. This process has roughly a 50% recovery rate.

British sustainable design company Gomi is giving 50,000 Lime e-bike batteries a second life by recycling them into zero-waste portable Bluetooth speakers.

Hydro Volt, that will build a recycling plant in Fredrikstad, Norway, for lithium-ion batteries from electric vehicles. Due to open in 2021, the plant will have initial capacity to crush and sort over 8,000 metric tons of batteries per year. Aluminium from the batteries will be reused by Hydro, and the remaining so-called black mass will be further processed by Northvolt in Västerås, Sweden. Northvolt is also building a large lithium-ion battery factory in Skellefteå, Sweden. The planned Hydro Volt facility marks a step toward Northvolt's goal of sourcing 50% of its raw materials from recycled batteries by 2030.

Ecobatt one of Australia's largest battery recyclers recycles all types of batteries to safely recover mercury, lead, silver, nickel, cadmium, steel, lithium and plastic. Whatever your needs, your battery waste specialist will work out the best battery disposal and collection solution for you.

Global materials technology and recycling group Umicore operates a plant capable of processing the 2 million e-bike batteries on the market but it only works if batteries come to them and aren't sent to landfill first. This requires a process for consumers and companies to send their batteries to a recycling plant.

The growing popularity of electric bikes has raised a lot of exciting possibilities about the future of transportation, but it also presents a few unique challenges. This extraction process comes with significant environmental impacts, mainly because of huge use of water and the pollution of other

local water sources by toxic chemicals, making the recycling facilities that much more important. The main issue with recycling lithium batteries is that the majority are stuck inside devices like laptops and phones, so they just go to landfill (Xiaodong Lai, 2020). With e-bikes, the battery can be easily removed making it theoretically very simple to recycle. However e-bike battery recycling systems are not widely availability, making it hard for individuals to dispose of their batteries. Without easy access to these disposal sites, batteries will end up in landfill. Government incentives and penalties can raise the awareness of the consumers on the importance of recycling (Guozhu Mao, 2021).

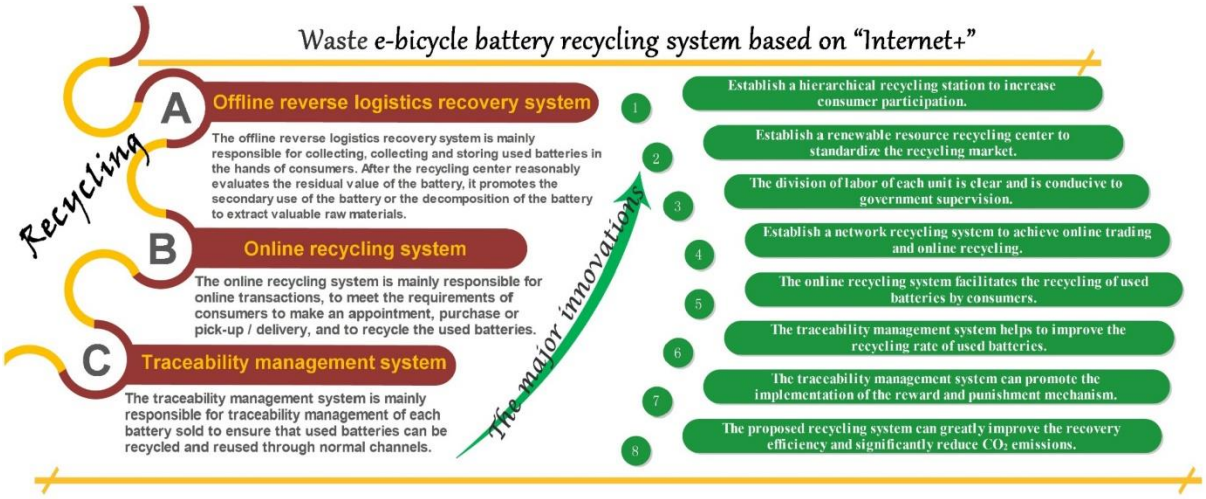

Figure 3: The major innovations of the proposed waste e-bicycle battery recycling system. (Jianzhou Wang, 2020)

The above Figure is a recycling system that highlights suggestions for the recycling of e-bicycle batteries. For batteries to be recycled safely and efficiently the government needs to establish regulations on the recycling of waste e-bicycle batteries, prohibiting the recycling of uncertified traders. Alternatively, local drop off points, potentially in shopping centres or bike shops could enable efficient transportation of batteries to the limited battery recycling plants a possibility.

Millions of e-scooters have been sold to individuals and to rideshare fleets, and tens of millions of e-scooter trips are taken per year (Mathew, Liu, Seeder, Li, & Bullock, 2019). It is expected that e-scooters will be overwhelmingly used only for short travel trips, not for entire commutes of many kilometres that can take half an hour or more. While e-scooters do not have the scope of travel distance bikes do, they still need effective recycling systems to minimise the waste they produce. E-scooters incorporate many of the technologies in e-bikes, batteries, GPS and data capabilities, app-based access, and availability through sharing platforms (Dimitri Marincek, 2020). This means that many of the same recycling systems could potentially be used it available.

Redesign Potential

Bikes are designed towards audiences that cares more about the environment, but the manufacturing processes have remained somewhat traditional, which reveals many inefficiencies when compared to current manufacturing trends (Rodríguez, 2019). While bike designs are made from a wide variety of materials and shapes that are adapted to the needs of each user, improvements can be made. Using new production methods, with less resources can achieve the

same or better results, such as additive manufacturing, the use of renewable materials, and the generative design process (Ryan Arlitt, 2016).

Manufacturing Bikes

Bike anatomy changes sightly depending on the style of bike, but the key components of a bike, tricycle or recumbent remain basically the same. This means that recycle methods can remain constant with bike variations (A Short Course In Bicycle Anatomy, 2020).

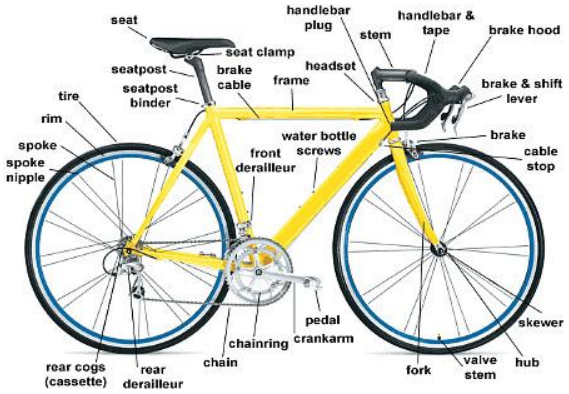

Figure 4: Anatomy of a Road Bike

Figure 5: Anatomy of a mountain bike

Developing a bike frame that brings both scope in manufacturability and sustainability is a part of creating a circular industry, that overcomes our current waste problems. With innovations it is possible to redefine bike products we don't think could be modified, even though bikes with their simple functionality, can be assumed to be at its full potential.

What is on Offer

Bikes are commonly considered a tool for environmental solutions. Increasing ridership reduces fossil fuel consumption, eases traffic congestion, and improves public health (Rebecca Johnson, 2014). Redesigning is a part of the waste solution. Currently, only four leading bicycle brands mention their sustainability or corporate social responsibility efforts online: Trek Bicycles; Specialized Bicycle Components, Accell Group, Raleigh and Dorel Industries, a publicly traded Canadian company that owns Cannondale (Accell Group, 2021) (Trek Bicycle Corporation, 2021) (Dorel Industries, 2021).

Based in Portland, ReCycle Bikes is a new business that hand-makes their bicycles with frames made of 80% recycled aluminum and other recycled material like cork for the seat. Other companies like Broomers are producing bamboo bike frames and Detroit Bikes are designing bikes with more sustainable frames. Chris King corporation prioritises reclaimed steel and aluminum, water-saving production methods to build bike parts.

Figure 3: ReCycle Bike (The ReCycle Cycles, 2021)

Currently disposing of a helmet in an environmentally responsible way is not easy, as most helmets contain plastic shell, EPS foam liner, nylon or polyethelene straps and a plastic buckle (Bicycle Helmet Safety Institute, 2020). EcoHelmet is a folding, recyclable, vendable helmet, designed for bike share systems. It is made of waterproofed paper in a unique radial honeycomb pattern, gives bike share users a helmet that can be purchased with the bike rental and recycled after the ride (The James Dyson Foundation, 2021).

Finally packaging is another area of great waste concerns in the bike community. Recently Cannondale has moved to 100% recyclable and plastic-free packaging with no cost to manufacturer or consumer so will hopefully inspire more brands to follow suit (LAUGHLIN, 2020). Trek is following suit with reduced non-recycle parts and a campaign to educate customers and retailers alike on safe and effective packaging disposal.

Overview

Nothing on a bike is permanent. Brake pads fade, tyres knobs are ground down and chains rust. This means that even with new emerging product designs and sharing systems available, waste recycling streams need to be built and widely available to ensure that users can dispose of bikes properly. There are organisations on their way to creating circular economies, but they are geographically constricted, and more organisations or national systems need to be built to ensure that bikes, helmets, tyres and batteries are all separated and recycled for further use. E-bikes and e-scooters are playing an even more fundamental role around the world. And while their batteries last hundreds of charges, they eventually they will reach the end of their life and will have to be disposed of. While there is no simple way to recycle bikes yet, there are organisations that have pathed the way to waste reduction systems.

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