PACE
PLATFORM FOR ACCELERATING THE CIRCULAR ECONOMY

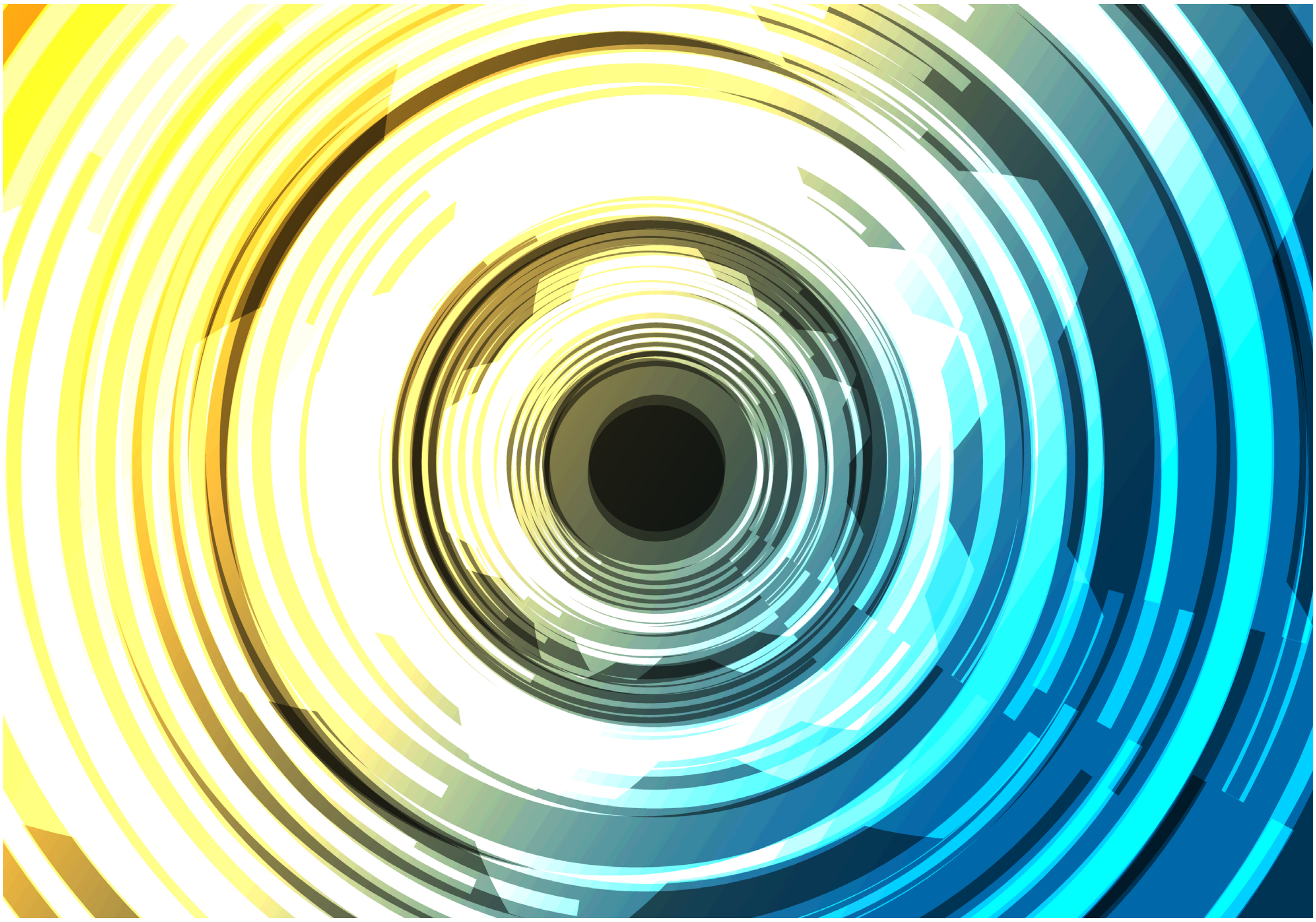
WORLD ECONOMIC FORUM

COMMITTED TO IMPROVING THE STATE OF THE WORLD

A New Circular Vision for Electronics
Time for a Global Reboot

In collaboration with the United Nations E-waste Coalition

January 2019



The Platform for Accelerating the Circular Economy (PACE)
This report is published as part of the Platform for Accelerating the Circular Economy (PACE). PACE is a public-private collaboration mechanism and project accelerator dedicated to bringing about the circular economy at speed and scale. It brings together a coalition of more than 50 leaders and is co-chaired by the heads of Royal Philips, the Global Environment Facility and UN Environment. It is hosted by the World Economic Forum.

The E-waste Coalition
This report supports the work of the E-waste coalition, a group of seven UN agencies who have come together to increase collaboration, build partnerships and more efficiently provide support to Member States to address the e-waste challenge. The coalition includes: International Labour Organization (ILO); International Telecommunication Union (ITU); United Nations Environment Programme (UNEP); United Nations Industrial Development Organization (UNIDO); United Nations Institute for Training and Research (UNITAR); United Nations University, and Secretariats of the Basel and Stockholm Conventions. It is supported by the World Business Council for Sustainable Development (WBCSD), the World Health Organization (WHO) and the World Economic Forum and coordinated by the Secretariat of the Environment Management Group (EMG).

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Foreword

We have come together as the heads of six UN agencies with the World Economic Forum and the World Business Council for Sustainable Development to address a severe global challenge while also simultaneously grasping a massive opportunity.

Electronic goods, from solar mini grids to smartphones, bring huge benefits to humankind and offer new opportunities for development. They present new tools to address the challenges of climate change, expand education, deliver healthcare and facilitate trade. Digitalization and connectivity are also critical to help achieve all 17 Sustainable Development Goals.

At the same time, the current system of production and consumption is ready for a reboot. In the mining, manufacturing, transport, retail, consumption and disposal of electronics, there are vast amounts of wasted resources and the system has several negative impacts. Each year, approximately 50 million tonnes of electronic and electrical waste (e-waste) are produced, equivalent in weight to all commercial aircraft ever built; only 20% is formally recycled. If nothing is done, the amount of waste will more than double by 2050, to 120 million tonnes annually.

When it is not being stored in cellars, drawers and cabinets, e-waste is often incinerated or dumped in landfills, or makes its way around the world to be pulled apart by hand or burned by the world's poorest, to the detriment of health and the environment.

That same e-waste represents a huge opportunity. The material value alone is worth $62.5 billion (€55 billion), three times more than the annual output of the world's silver mines and more than the GDP of most countries. There is 100 times more gold in a tonne of mobile phones than in a tonne of gold ore. Furthermore, harvesting the resources from used electronics produces substantially less carbon-dioxide emissions than mining in the earth's crust. Working electronic goods and components are worth more than the materials they contain. Therefore, extending the life of products and re-using components brings an even larger economic benefit.

There is also an opportunity to build a more circular electronics system, one in which resources are not extracted, used and wasted, but valued and re-used in ways that create decent, sustainable jobs. In short, we need a new vision for electronics.

This report combines data and research from throughout the UN system to make the case for a new vision. Describing and analysing challenges and opportunities, and laying the groundwork for the process of systemic change is just the first step. To make this happen, the following are required:

- Vision: Society needs to collectively rethink the rules of the game and create a vision around which government, consumers and industry can rally
- Awareness: The public needs to learn more about this growing global challenge and opportunity
- Collaboration: This coalition seeks to work with multinationals, small and medium-sized enterprises (SMEs), entrepreneurs, academia, trade unions, civil society and associations in a specific and deliberative process to bring about change. Public-private collaborations through platforms such as PACE and the E-waste Coalition will play an important role
- Action: Coordinated action by all actors is needed within and across national borders

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Executive Summary

Rapid innovation and lowering costs have dramatically increased access to electronic products and digital technology, with many benefits. This has led to an increase in the use of electronic devices and equipment. The unintended consequence of this is a ballooning of electronic and electrical waste: e-waste.

It is difficult to gauge how many electrical goods are produced annually, but just taking account of devices connected to the internet, they now number many more than humans. By 2020, this is projected to be between 25-50 billion,[1,2] reflecting plummeting costs and rising demand.

E-waste is now the fastest-growing waste stream in the world.[3] Some forms of it have been growing exponentially.[4] The UN has called it a tsunami of e-waste.[5,6] It is estimated this waste stream reached 50 million tonnes in 2018.[7] This figure is expected to double if nothing changes.[8] Globally, society only deals with 20%[9] of e-waste appropriately and there is little data on what happens to the rest, which for the most part ends up in landfill, or is disposed of by informal workers in poor conditions.

Yet e-waste is worth at least $62.5 billion[10] annually, which is more than the gross domestic product (GDP) of most countries. In fact, if e-waste was a single nation, it's GDP would be on a par with that of Kenya. Furthermore, 123 countries have less GDP than the global pile of electronic waste.[11] In the right hands, however, it could be worth considerably more.

Changes in technology such as cloud computing and the internet of things (IoT) could hold the potential to "dematerialize" the electronics industry. The rise of service business models and better product tracking and take-back could lead to global circular value chains. Material efficiency, recycling infrastructure and scaling up the volume and quality of recycled materials to meet the needs of electronics supply chains will all be essential. If the sector is supported with the right policy mix and managed in the right way, it could lead to the creation of millions of decent jobs worldwide.

A new vision for the production and consumption of electronic and electrical goods is needed. It is easy for e-waste to be framed as a post-consumer problem, but the issue encompasses the lifecycle of the devices everyone uses. Designers, manufacturers, investors, traders, miners, raw material producers, consumers, policy-makers and others have a crucial role to play in reducing waste, retaining value within the system, extending the economic and physical life of an item, as well as its ability to be repaired, recycled and reused. The possibilities are endless.

This is an inflection point in history and represents an unparalleled opportunity for global businesses, policy-makers and workers worldwide. Those who can rethink the value chain for electronic goods and prioritize dematerialization and closed loop systems (which means reducing reliance on primary resources), could have an incredible advantage. Innovative products and services do not have to mean more e-waste; they can mean a lot less.

The prevailing "take, make and dispose" model has consequences for society, a negative impact on health and contributes to climate change.[12] It is time for a system update. We need a system that functions properly – in which the circular economy replaces the linear – needs to be created.

In the short-term, electronic waste remains a largely unused, yet growing, valuable resource. Nearly all of it could be recycled. Urban mining, where resources are extracted from complex waste streams, can now be more economically viable than extracting metal ores from the ground. It is largely less energy intensive. E-waste can be toxic, is not biodegradable and accumulates in the environment, in the soil, air, water and living things. It can also have an adverse impact on health. Children and women are particularly vulnerable to the health risks of e-waste exposure.[13]

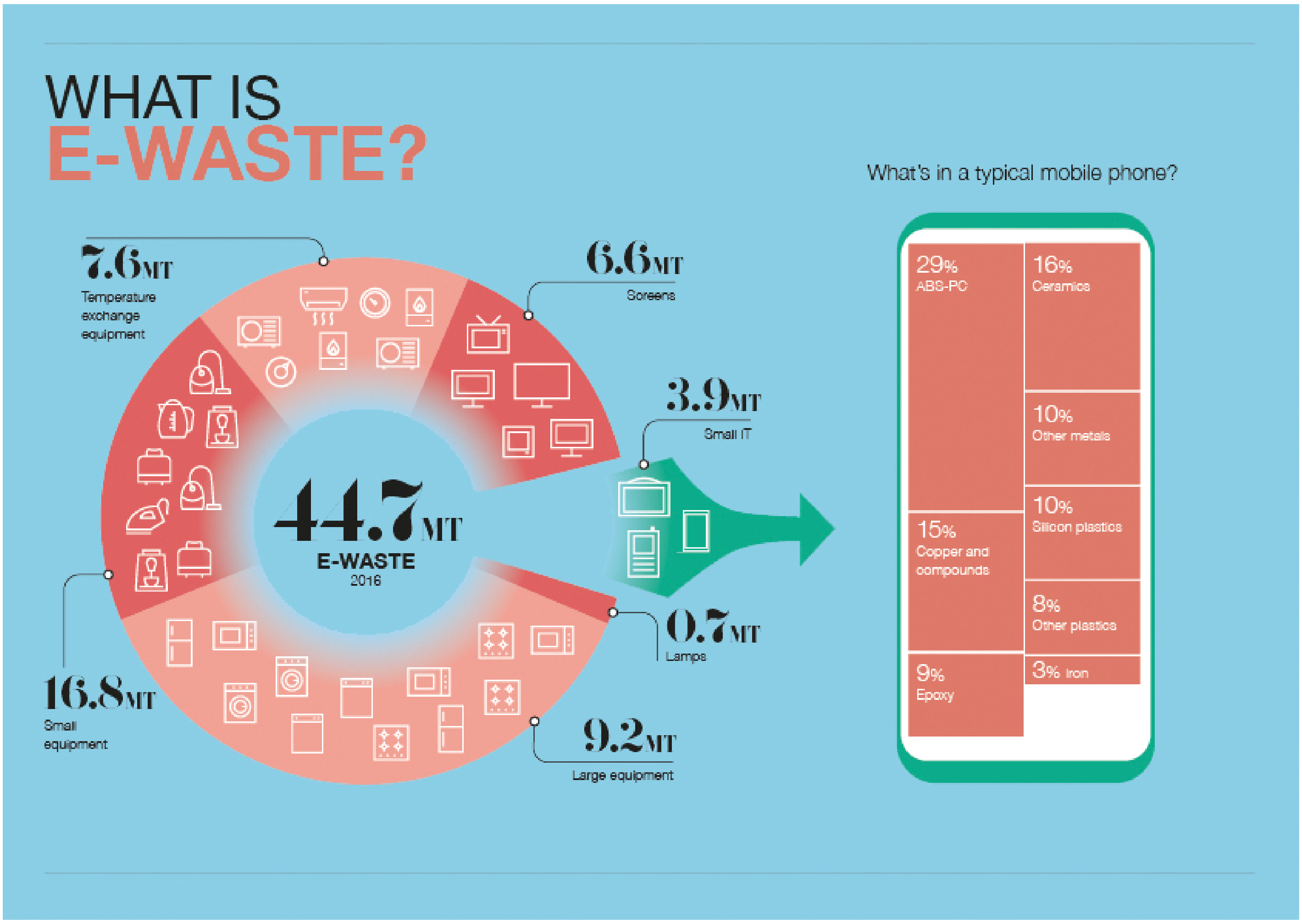
It is time to reconsider e-waste, re-evaluate the electronics industry and reboot the system for the benefit of industry, consumer, worker, health of humankind and the environment. The incredible opportunities here are also aligned to the globe's "just transition" to environmental sustainability and to shaping a future that works for all in the circular economy.

E-waste defined

E-waste is defined as anything with a plug, electric cord or battery (including electrical and electronic equipment) from toasters to toothbrushes, smartphones, fridges, laptops and LED televisions that has reached the end of its life, as well as the components that make up these end-of-life products. E-waste is also called waste electrical or electronic equipment, or WEEE for short.[14] Currently, only a few countries have a uniform way of measuring this waste. E-waste comes from many sources including households, businesses and governments.

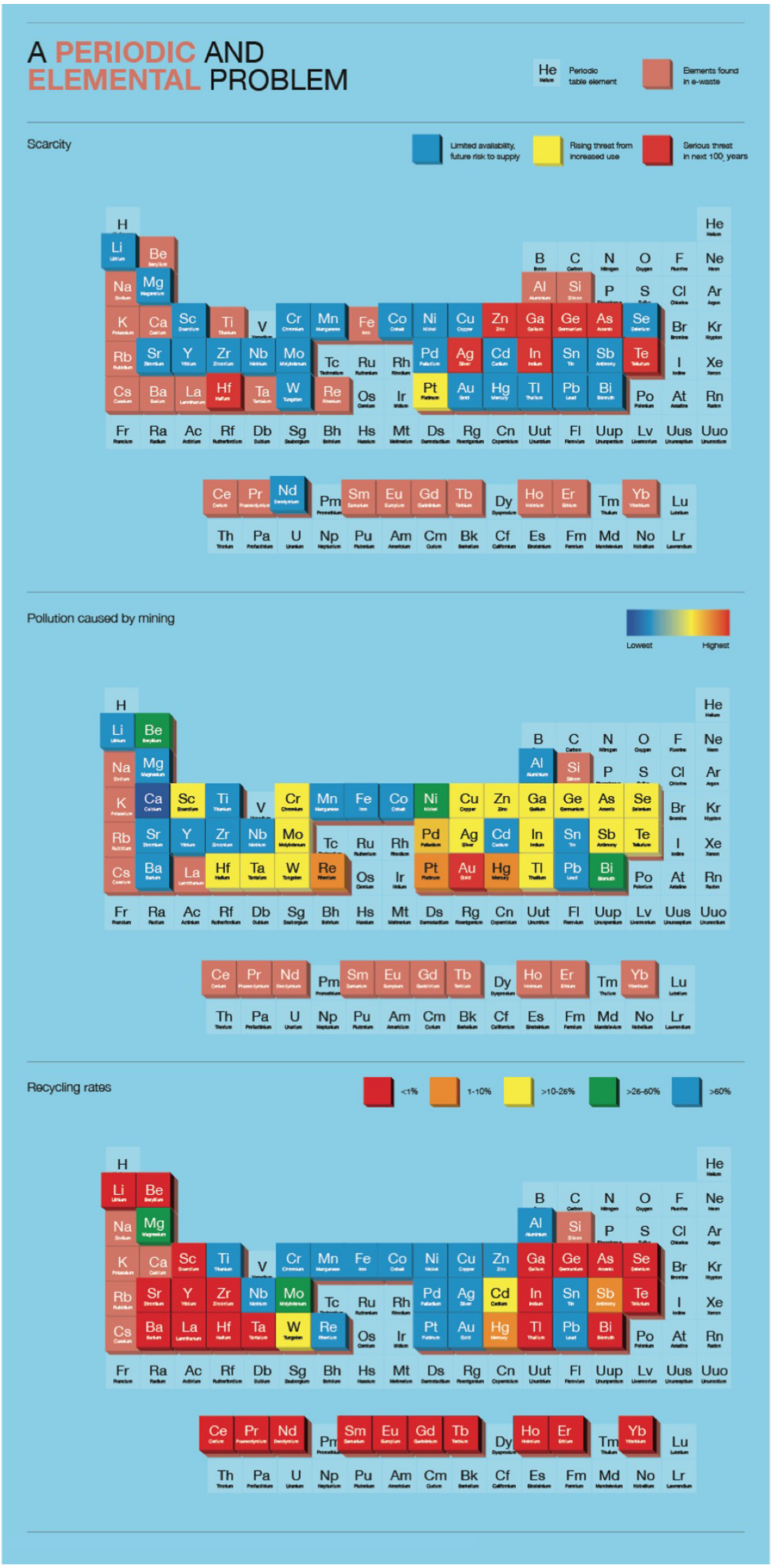
E-waste may contain precious metals such as gold, copper and nickel as well as rare materials of strategic value such as indium and palladium. A lot of these metals could be recovered, recycled and used as secondary raw materials for new goods. The challenge is the incredible complexity of doing this; a product can be made up of more than 1,000 different substances.[15] E-waste may represent only 2% of solid waste streams, yet it can represent 70% of the hazardous waste that ends up in landfill.[16,17] Up to 60 elements from the periodic table can be found in complex electronics,[18] such as smartphones, with many being technically recoverable.

Figure 1: What is in E-waste?



Source: Global E-waste Monitor, 2017

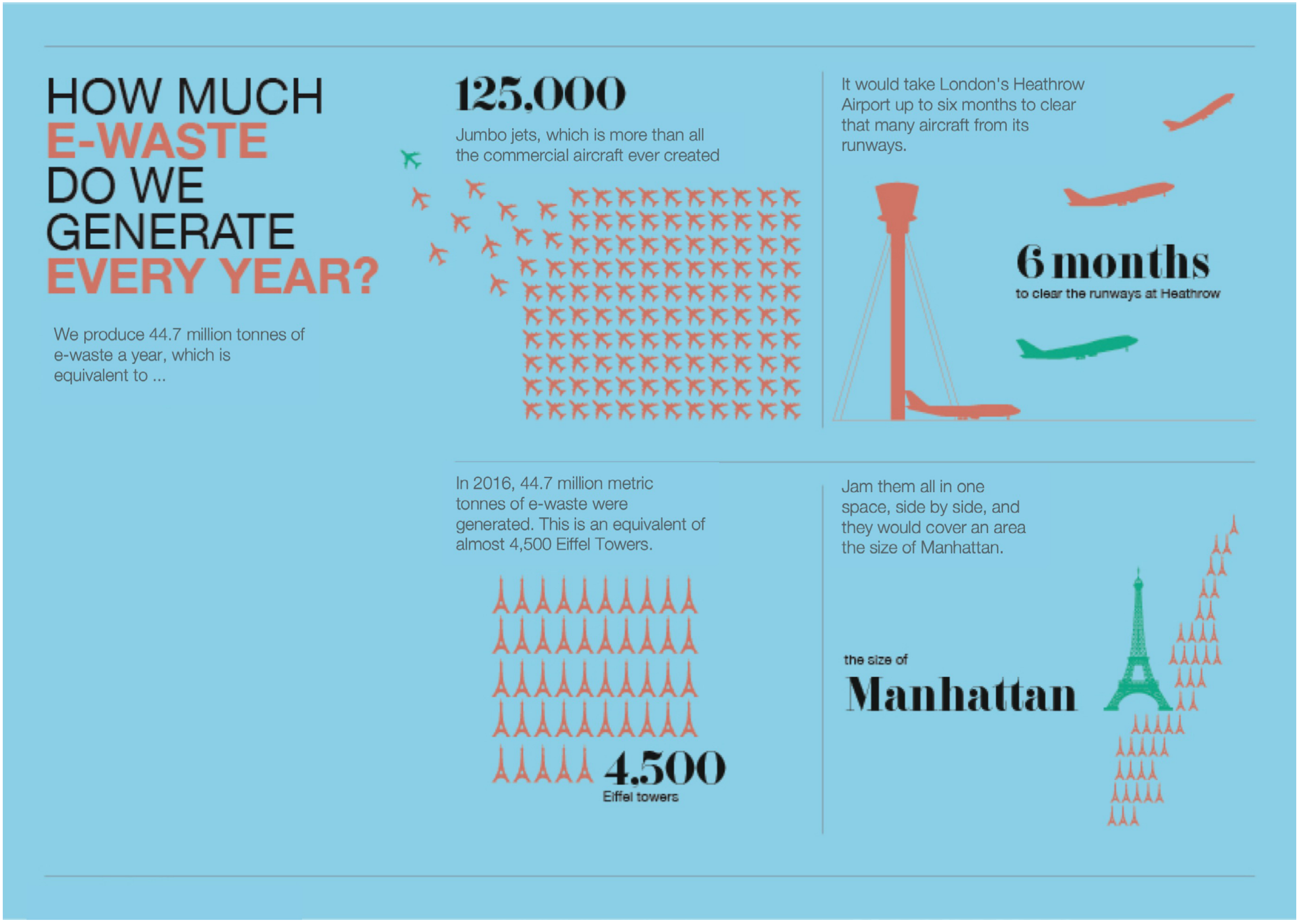
Figure 2: A Periodic and Elemental Problem



Source: UNU, 2015; UNI, 2014

The scale of e-waste

Figure 3: How much e-waste do we generate every year?



Source: E-waste Monitor, 2017

According to the Global E-waste Monitor 2017, in one year, a staggering 44.7 million metric tonnes of e-waste are generated. This is equivalent to just over six kilograms for every person on the planet. Europe and the US alone contribute to almost one-half of the total e-waste generated annually.[19]

One-half of all e-waste is personal devices, such as computers, screens, smartphones, tablets and TVs, and the rest is larger household appliances, as well as heating and cooling equipment. The scale of global e-waste defies comparison, yet the weight is more than all the commercial aircraft ever produced. Imagine the mass of 125,000 jumbo jets[20] – it would take London's Heathrow Airport up to six months to clear that many aircraft from its runways. If you find that difficult to envisage, then try the mass of 4,500 Eiffel Towers, jam them all in one space, side by side, and they would cover an area the size of Manhattan.

Of this total amount, 40 million tonnes of e-waste are discarded in landfill,[21] burned or illegally traded and treated in a sub-standard way every year.

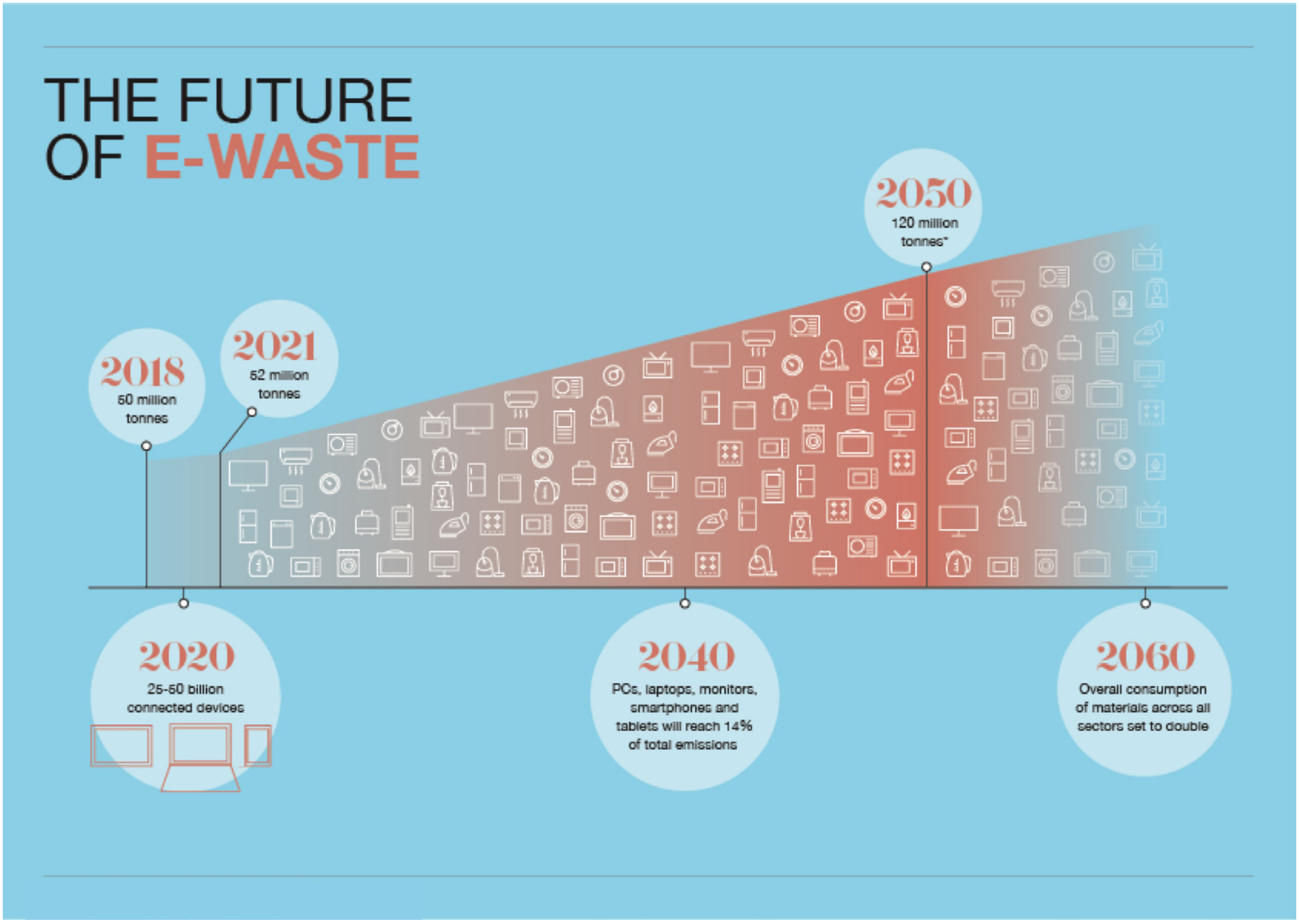
Trends

It is hard to forecast the volumes of e-waste that will be generated, but by 2021 the annual total volume is expected to surpass 52 million tonnes.[22] There are other indications that there will be a growth in the usage of electronic and electrical devices. For instance, forecasts put the number of devices connected to the internet at between 25-50 billion by 2020,[23] which is nearly triple the number of people on the planet today, all of these devices will have an end-of-life point. Most of the growth is coming from emerging regions, which are increasingly joining the connected global economy.

By 2040, carbon emissions from the production and use of electronics, including devices like PCs, laptops, monitors, smartphones and tablets (and their production) will reach 14% of total emissions.[24,25] This is one-half that of the total global transport sector today. By 2050, the volume of e-waste, in the worst-case scenario, could top 120 million tonnes annually, according to estimations from the United Nations University in Vienna.[26] According to the Organisation for Economic Cooperation and Development (OECD), by 2060, the world's consumption of raw materials is set to double.[27]

E-waste today often consists of products from the past. Think of the millions of cathode ray tubes from old televisions and computer monitors, VHS tapes and DVD players, many with toxic compounds, such as lead, still making them hazardous and problematic. There is a trail of e-waste generated from old technology that needs to be addressed.

Figure 4: The future of e-waste



Source: UNU, 2018; OECD, 2018

Resource scarcity, extraction and emissions

There are concerns about the availability and supply of new materials for electronics and electrical devices in the future. Rising commodity prices have highlighted risks. Yet e-waste contains many high-value and scarce materials, such as gold, platinum, cobalt, rare earths, and high quantities of aluminium and tin. There are many opportunities for better recovery.

It is uncommon to throw away gold, silver or platinum jewellery, but that is not true of electronic and electrical goods containing the same precious metals; up to 7% of the world's gold may currently be contained in e-waste.[28]

The improper handling of e-waste is resulting in a significant loss of scarce and valuable raw materials, including such precious metals as neodymium (vital for magnets in motors), indium (used in flat panel TVs) and cobalt (for batteries). Almost no rare earth minerals are extracted from informal recycling, these are polluting to mine.

Yet metals in e-waste are difficult to extract; for example, total recovery rates for cobalt are only 30% (despite technology existing that could recycle 95%).[29] The metal is, however, in great demand for laptop, smartphone and electric car batteries. Recycled metals are also two to 10 times more energy efficient than metals smelted from virgin ore. Furthermore, mining discarded electronics produces 80% less emissions of carbon dioxide per unit of gold compared with mining it from the ground.[30]

In 2015, the extraction of raw materials accounted for 7% of the world's energy consumption.[31] This means that moving towards the use of more secondary raw materials in electronic goods could help considerably in reaching the targets set out in the Paris Agreement on climate change.

Batteries: An electrifying issue

Like other components of modern electronics, batteries are everywhere. Nearly all portable and movable pieces of technology use them – from hearing aids and toys, to electric vehicles and smartphones. Yet they are not counted in global e-waste flows. Batteries normally contain one or more of the following nine metals: lithium, cobalt, cadmium, lead, zinc, manganese, nickel, silver or mercury.

The lithium-ion battery market, the fastest-growing segment, is forecast to reach $100 billion by 2025.[32] Batteries are dropping in cost and demand is rising, driven by demand from smartphone and electric vehicle usage. By 2030, there could be up to 125 million electric vehicles on the road, up from 3 million in 2018, ushering in a green transport revolution.[33] Currently, the global recycling rate for this market is only 42%.[34] By 2025, the weight of lithium-ion batteries being sold each year will increase five-fold to nearly 5 million tonnes.[35]

Electric vehicle batteries often contain as much lithium as 1,000 smartphones. The EU and People's Republic of China have introduced laws making carmakers responsible for recycling batteries. There is also the potential for a large market for second-life batteries; renewable energy grids of the future will need vast amount of storage, which could be filled by batteries that are too old for cars, but good for static uses.

Over 11 million tonnes of used lithium-ion batteries are forecast to be discarded by 2030, representing a significant challenge,[36,37] but also an opportunity given the dramatic rise in demand for materials such as lithium is and cobalt by 11 times.[38]
In electronics, device collection remains critical and, as with all components, will be important for the increased collection of batteries for recycling. When a battery has reached the end of its life it will be essential to ensure those batteries are destined for best-in-class recyclers who have the technology to recover the key raw materials. This can be helped by linking services to replace batteries with recyclers and ensuring batteries are not disposed of inappropriately.

One of the most important materials for battery production is cobalt, yet two-thirds of the world's cobalt is found in one of the world's poorest countries, the Democratic Republic of the Congo (DRC). About 90% of the cobalt produced in DRC, originates from large-scale and mechanized mining operations. However, 10% is estimated to originate from small-scale mining, often in dangerous working conditions. Amnesty international has reported that child labour is widespread in this informal sector.[39]

Efforts are under way to address these challenges, which span the lifecycle and value chain of battery technology. Notably, the Global Battery Alliance is a public-private partnership and collaboration platform, which seeks to provide a platform to accelerate these efforts and build a sustainable value chain for batteries.

Growing PV solar panel usage and the subsequent e-waste it produces, presents a similar environmental challenge, but also unprecedented opportunities to create value and nurture new end-of-life industries.[40]

A system error

Consumer relationships with electronics

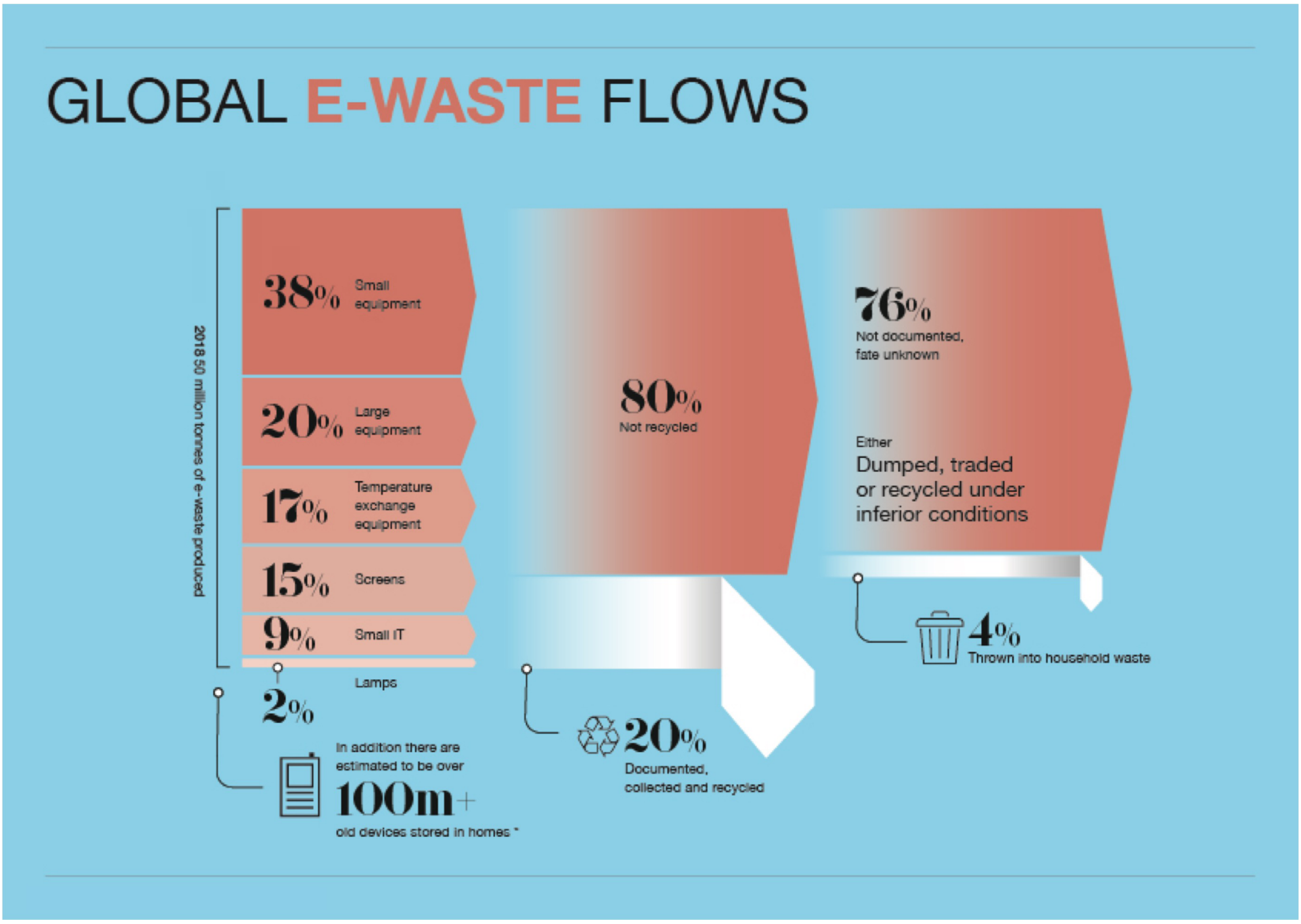
Like fast fashion and fast food, electronics can involve a rapid turnover in style trends, with revenues dependent on selling the latest products, which are increasingly affordable. In particular, affordability has opened up opportunities in developing countries, for instance mobile money has dramatically increased financial inclusion and given rise to other developmental opportunities. In many cases, second-hand device markets flourish in these countries with products such as laptops and smartphones having second or third lives. Yet eventually all these smartphones, tablets, cameras and home gadgets or appliances will become waste.

One report puts the global consumer electronics market at around $1.1 trillion in 2017, growing at a rate of 6% until 2024, when it will be worth $1.7 trillion.[41] Rising smartphone adoption rates are fuelling global demand. There is also a major trend towards flat panel TV screens in developed markets and adoption of 3G and 4G in developing economies; electric vehicles are also on the rise. More clothes, furniture, toys, sports equipment and toothbrushes have complex electronic components.

Lack of recycling

Recycling rates globally are low. Even in the EU, which leads the world in e-waste recycling, just 35% of e-waste is officially reported as properly collected and recycled.[42] Globally, the average is 20%; the remaining 80% is undocumented, with much ending up buried under the ground for centuries as landfill.[43] E-waste is not

Figure 5: Global e-waste flows



Source: Global E-waste Monitor, 2017

biodegradable. The lack of recycling weighs heavily on the global electronic industry and as devices become more numerous, smaller and more complex, the issue escalates.

Currently, recycling some types of e-waste and recovering materials and metals is an expensive process. The remaining mass of e-waste – mainly plastics laced with metals and chemicals – poses a more intractable problem. The waste stream is complex, containing up to 60 elements from the periodic table. In some cases, it contains hazardous chemicals, such as flame retardants, of which some are Persistent Organic Pollutants listed under the Stockholm Convention.

There is also confusion in global consumers' minds in terms of how they handle e-waste because the system is often complex. In many cases, it is treated as normal household waste, but it must be separated. Different streams of e-waste must also be dealt with separately, including batteries, light bulbs, smartphones, cables or computers.

This lack of awareness about how to recycle and worries about data security mean there are vast tranches of residual electronics sitting in drawers, garages, bedrooms and offices across the globe waiting to be dealt with. An opportunity in waiting.

Labour, environmental and health issues

From lead-lined, cathode ray tubes from old TVs, to lead and chromium in circuit boards, e-waste can contain substances that are hazardous to human health if not dealt with properly, including mercury, cadmium and lead. E-waste can pollute water sources and food supply chains. This is particularly true of older products making up today's e-waste. Regulation and some voluntary targets are driving the phase out of some of the worst offenders in new products.

Recycling of valuable elements contained in e-waste, such as copper and gold, has become a source of income, mostly in the informal sector of developing countries. However, basic recycling techniques to burn the plastic from electronic goods leaving the valuable metals, melting down lead in open pots, or dissolving circuit boards in acid) lead to adult and child workers, as well as their families, exposed to many toxic substances.

In many countries, women and children make up to 30% of the workforce in informal, crude e-waste processing and are therefore particularly vulnerable.[44] When the mothers of tomorrow are exposed to toxic compounds, there are also potential issues.[45] Findings from many studies show increases in spontaneous miscarriages, still and premature births, as well as reduced birthweights and birth lengths associated with exposure to e-waste. Workers also suffer high incidences of birth defects and infant mortality. E-waste compounds are also carcinogenic. Toxic elements are found in the blood streams of informal workers at dumping grounds for e-waste where open burning is used to harvest metals. These dumps have become economic hubs in their own right, attracting food vendors, and are often adjacent to informal settlements, leading to further contamination from the toxic fumes. E-waste can contaminate groundwater, soil and air.[46]

Today, the total number of people working informally in the global e-waste sector is unknown. However, according to the ILO in Nigeria up 100,000 people are thought to be working in the informal e-waste sector, while in China that number is thought to be 690,000.[47] The upgrade and formalization of the industry to one where formal recycling plants provide safe, decent work for thousands of employees is a major opportunity.

It is also worth considering the effects electronic goods have on climate change. Every device ever produced has a carbon footprint and is contributing to human-made global warming. Manufacture a tonne of laptops and potentially 10 tonnes of CO^2 are emitted. When the carbon dioxide released over a device's lifetime is considered, it predominantly occurs during production, before consumers buy a product. This makes lower carbon processes and inputs at the manufacturing stage (such as use recycled raw materials) and product lifetime key determinants of overall environmental impact.[48]

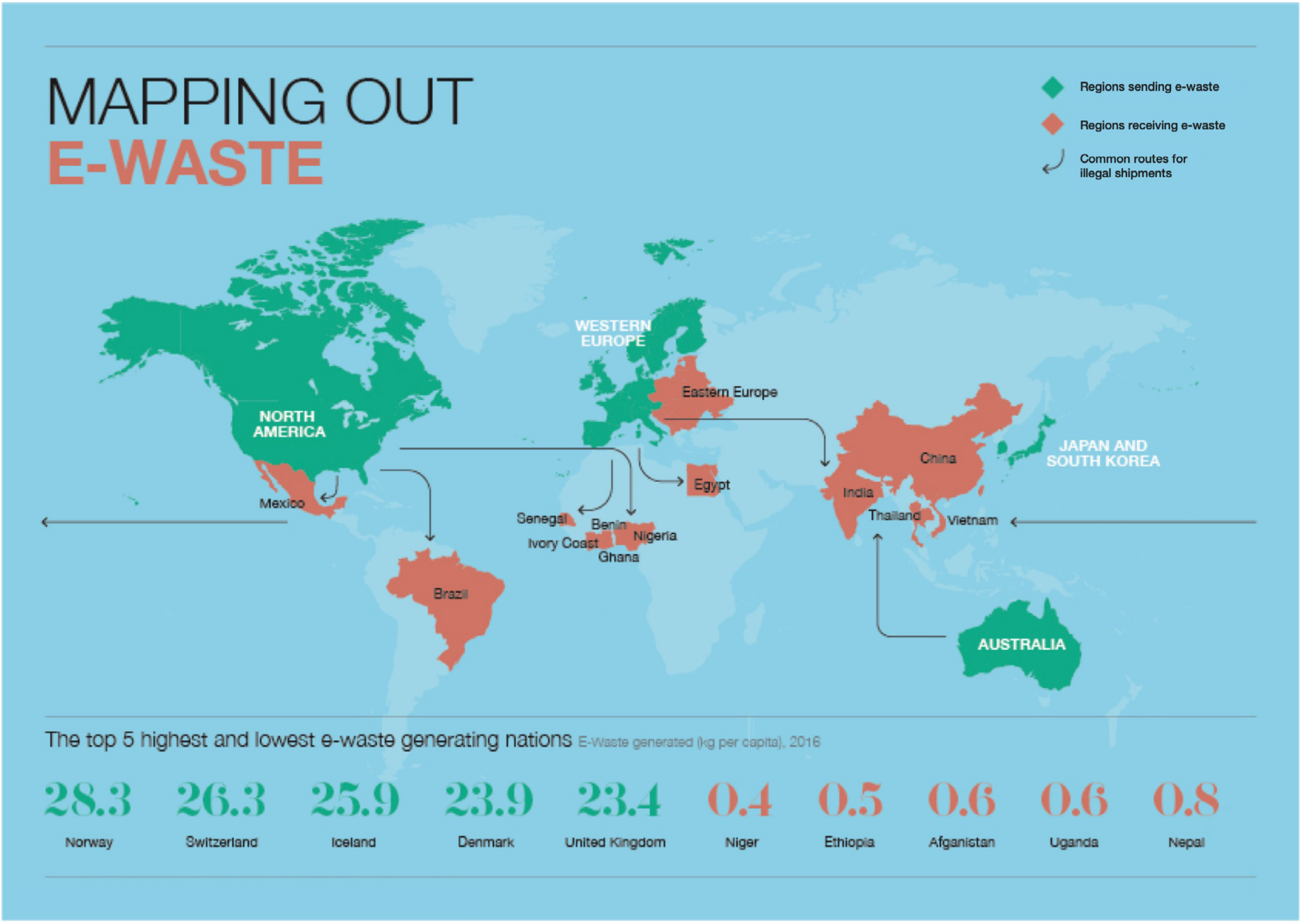
Legislation on e-waste

A total of 67 countries have legislation in place to deal with the e-waste they generate. This normally takes the form of Extended Producer Responsibility, when a small charge on new electronic devices subsidizes end-of-life collection and recycling. The legislation covers about two-thirds of the global population.[49] However, many countries do not have national legislation on e-waste. In many regions of Africa, Latin America or South-East Asia, electronic waste is not always high on the political agenda, and often not well enforced.

When it comes to the export of e-waste to developing countries, it is regulated under the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, which has been ratified by 187 countries, other similar conventions exist at a regional level.[50] Even with these conventions in place, however, large amounts of e-waste continue to be shipped illegally. The difference in enforcement of conventions and transposing e-waste legislation globally means the regulatory environment can be complex and fragmented.[51]

Where is e-waste generated?

Figure 6: Mapping out e-waste



Source: Lewis 2011, The Global E-waste Statistics Partnership, 2018

Australia, China, the EU, Japan, North America and the Republic of Korea produce most of the world's e-waste. In the United States and Canada, every person produces roughly 20kg of e-waste annually, while in the EU the figure stands at 17.7kg. Yet the 1.2 billion inhabitants of the African continent each generated an average of just 1.9kg of electronic waste.[52]

In total, 1.3 million tonnes of discarded electronic products are exported from the EU in an undocumented way every year. The illegal movement of e-waste from developed countries to developing countries is a major global challenge. There is a complex web of trans-shipment ports so that e-waste avoids detection by authorities.[53]

At the same time, shipments of secondary materials from consumer countries to centres of production with the intention of re-integrating materials into new products would benefit from clear international definitions on secondary materials. Shipments of used products for repair, refurbishment or direct re-use are subject to legislative uncertainties.

The economic value of e-waste

There is a lot of economic value in e-waste, particularly from such materials as gold, silver, copper, platinum and palladium, among others. There is 100 times more gold in a tonne of smartphones than in a tonne of gold ore. The earth's richest deposits of valuable materials are sitting in landfill sites or people's homes. More needs to be made of these resources.

Looking at the market for smartphones, 1.46 billion were sold in 2017.[54] At retail, each unit contains electrical components worth more than $100.49 This represents a lot of value entering the market each year. If just the raw materials are recycled, they could be worth up to $11.5 billion.[55] The latest forecasts show that e-waste is worth $62.5 billion annually, which is more than the GDP of most countries. It is also worth three times the output of all the world's silver mines.

A more effective use of products is a second life, which keeps the materials at a higher value. Global markets for second lives of smartphones are well developed, particularly at the top end of the market. There is, however, significant room for improvement.

In 2016 alone, 435,000 tonnes of phones were discarded,[56] despite containing billions of dollars' worth of materials.

To capture this opportunity, it will be important to move towards a circular economy for electronics.

Delivering a zero e-waste circular economy

A system upgrade: Change to the circular economy

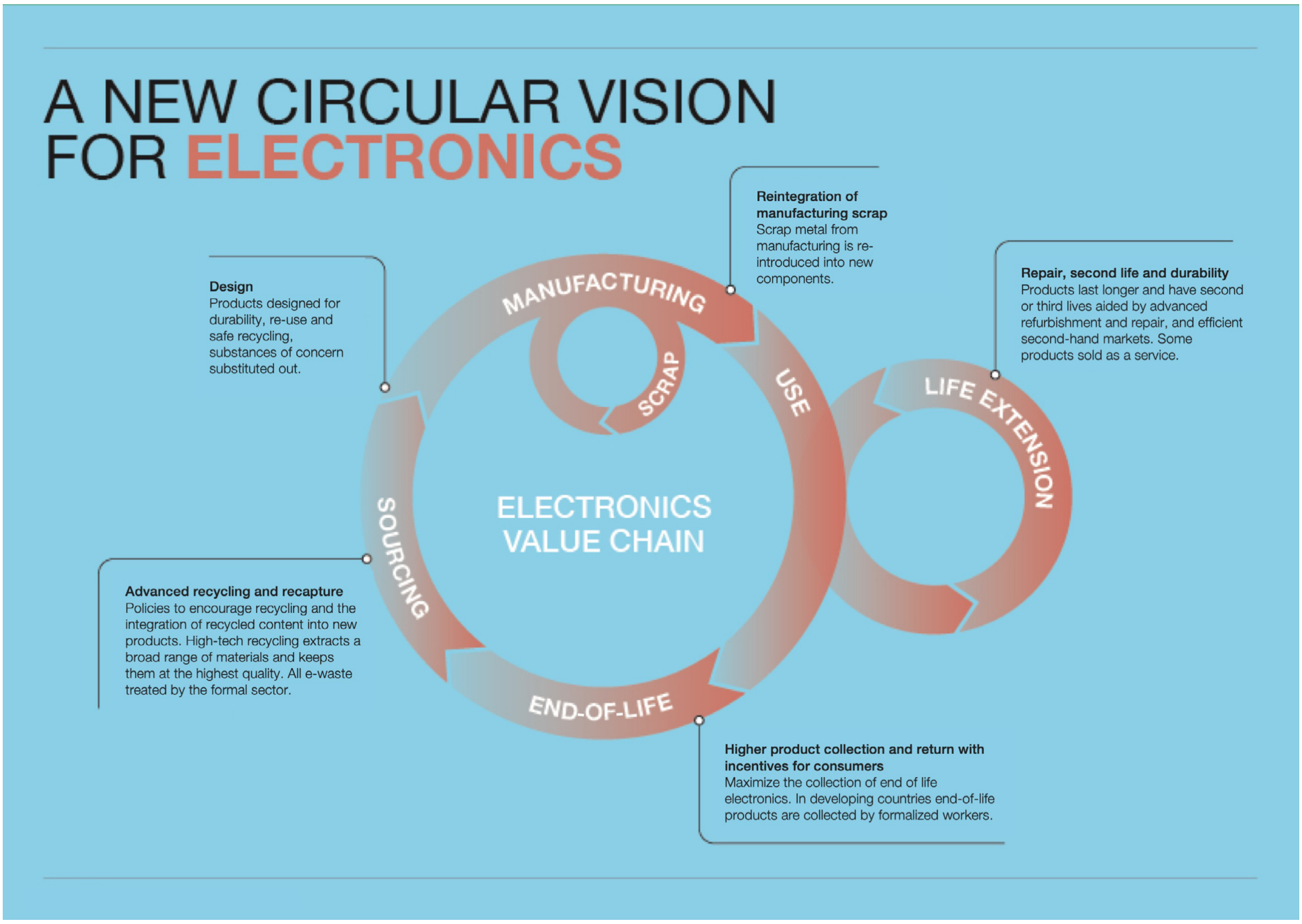
A circular economy is a system in which all materials and components are kept at their highest value at all times, and waste is designed out of the system. It can easily be thought of as the opposite of today's linear economy. It can be achieved through different business models including product as a service, sharing of assets, life extension and finally recycling. To build a circular economy for electronics there are different aspects to consider.

Design

Products need to be designed for reuse, durability and eventually safe recycling. Many companies have made global commitments to designing waste out of the electronics value chain and others have worked hard to design hazardous materials out of their products. These kinds of experiences must be shared across the industry, creating a pre-competitive, open-source space for collaboration.

Embracing durable designs can ensure that electronic devices are kept in circulation for longer. Configurations should have a product's end-of-life in mind, as well as encouraging disassembly and reuse. Taking a "systems approach" and redesigning the entire electronic device lifecycle for a circular economy could also create more value in the system.

Figure 7: A new circular vision for electronics



Source: Prepared for this report by participating organizations

Buy-back or return systems
Increasingly producers of electronics could offer buy-back or return systems for old equipment. Incentivizing the consumer financially and guaranteeing their data will be properly handled. Expertise in user experience could be employed to make the end-of-life process smoother.

Advanced recycling and recapturing
Companies and governments could work towards creating a system for closed-loop production in which all old products are collected and then the materials or components re-integrated into new ones. This will take new financial incentives and policy levers as well as private-sector leadership. The recycling sector will also need an upgrade; in some cases, recycled materials are not of sufficient quality for use in new electronic products. Countries also have targets related to this. In China, there is a target for 20% recycled content in all new products by 2025.

Durability and repair
Post-consumer recycling of electrical and electronic goods will not be enough to combat the issue. Society must be able to benefit from well designed, long-living products. Longevity can be further increased when equipment is maintained, repaired, and refurbished. Companies should be ready to repair equipment they sell, something that has also been mandated by law in some jurisdictions. Second-hand electrical goods are worth more than individual components, which again are worth an order of magnitude more than the materials alone. Therefore, second use and harvesting components represent a major opportunity.

Urban mining
It is time for companies to start investing heavily around the globe in technology that can help extract metals and minerals from e-waste. Already one recycler in China produces more cobalt than the country mines in one year. A circular economy for electronics would maximize the amount of valuable e-waste that moves back into the production of new electronic products and components. To get there, more countries, especially those in the developing world, will need to adopt e-waste legislation, such as extended producer responsibility and build a formal recycling industry. Not only will this mitigate some of the worst effects, but it will also create a huge opportunity for economic growth and decent work.

Reverse logistics
When a product can no longer be used, the materials will need to be collected and sent back to be reintegrated into production. This is known as a reverse supply chain. Unlike a forward supply chain, however, the movement and processing of materials are not subsidized by the value of a finished product laden with features. Instead they must rely on the value of the raw materials only and therefore demand a highly efficient and economical reverse supply chain model that is safe and responsible, and ensures materials do not flow into the informal sector.

Electronics as a service?

Once there were vinyl records, then tapes and CDs. Our electronics devices have now have subscription-based streaming apps. VHS, DVDs and Blu-ray discs disappeared with the advent of Netflix. Some people use taxi haling apps instead of buying a car or stay in someone's spare room through Airbnb meaning less hotels are needed to cover peak times.[57] These are all now services that were once only sold as physical products.

The process is called dematerialization and is happening in many aspects of people's lives. In the Netherlands, Signify (formerly Philips Lighting) sells lighting as a service, and in the UK, Rolls Royce sells aeroplane engine time rather than jet engines. These are examples of electronics as a service.

Current leasing and rental models, with monthly contracts say for smartphones and even some televisions, allow global consumers to access the latest technology, particularly products with short lifespans and without high up-front costs. Access to innovation and upgrades continues unabated, while barriers to usership have also lowered.

With this new ownership model, the manufacturer has an insensitive to ensure that all the resources are used optimally over a device's lifecycle. This includes when it is time to be reused by another consumer or recycled. For this to work, however, it is vital that products are kept as services until their last use, or they risk being sold and falling into the informal sector. There is also an incentive to keep the value in products for as long as possible, extend the life of devices, repair them when necessary, eliminate waste and reduce the impact that electronic products have on the environment.

Instead of a one-off transaction, the business model shifts to one of an ongoing service, and the subscription economy. This builds a much closer and stronger customer relationship. This has already occurred with household modems in some countries. For example, Fairphone, a circular mobile phone company in the Netherlands, has launched "Fairphone-as-a-Service"[58] and Dell in the US already has "PC as a Service".[59,60]

As outlined in a recent report by the Ellen MacArthur Foundation, the rise of cloud computing also has incredible potential when it comes to electronics. By moving the capability of devices away from the actual hardware purchased and into remote data centres, hardware capabilities become less important than connectivity and services. In turn, this could increase product use cycles and decrease waste in the system.[61]

Economic benefit and job creation

The economic benefits of employing a circular economic model in the electronics and electrical sector could be enormous. A circular model for electronics could reduce the costs for consumers by 7% by 2030 and 14% by 2040.[62]

Since e-waste is a growing resource and given resource scarcity and price fluctuations for some metals and minerals on the horizon, there is a growing economic case for the recovery of these precious resources. This, combined with better designs and technology for resource recovery, will produce more profitable yields of materials, reinforcing the case.

In many countries, e-waste entrepreneurs and cooperatives of e-waste workers are expanding e-waste recycling operations and experimenting with new and inclusive business models for managing e-waste effectively. These have already generated thousands of decent jobs in safe conditions for what were formerly informal workers in the e-waste value chain. With the right policy mix and access to finance, such approaches could be expanded and scaled up, generating additional jobs for tens if not hundreds of thousands of workers in the circular economy.

If developed in the right way, employing a circular economy for the electronics and e-waste sector could create millions of jobs worldwide. Some may be in low-paid and low-skilled work as more e-waste is reclaimed into the system, but over time, this will change. This will give rise to the need for new designers, circular economists and urban mine specialists and EaaS (electronics as a service) officers. The future is bright.

Conclusion

This is an initial explainer on the challenge and opportunity of materials within the electronics and electrical equipment industry. It sets the framing for why the time has come for a global reboot of the electronics system and why we need a new vision for circular electronics. It is based on existing data and expert input. The paper starts to explore some of the levers that may play a part in that vision, but far more work is needed to collaborate with all the relevant players in the value chain and jointly create a vision. In turn, this can act as a map to transform the industry from one characterized by waste and a number of negative externalities, to one based on a circular economy.

The transition to a circular economy must take place in a way that benefits all stakeholders from the consumer to workers, government, businesses entrepreneurs and society at large. There will be a need for mass collaboration, system changing ideas, new policy frameworks and new ways of doing business. The organizations involved in this work have a joint commitment to achieve this and invite others to join in this important endeavour.

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