E-Waste: taking responsibility

IFIP Position Paper

1 - Introduction

Information and Communication Technologies (ICT) are often presented as tools that are put to use towards desirable outcomes, such as efficiency, development, security, and now also sustainability. ICT for sustainabilility and Green IT are increasingly promoted as fields that will produce new knowledge for more sustainable products and practices, countering current challenges such as climate change and non-renewable energy use. In the discourse on the new role of ICT, the sustainability of ICT itself remains invisible. For example, in 2016, the world produced almost 50 million tons of electronic waste, of which a large part is considered hazardous waste. Currently, 80% of e-waste is unaccounted for in terms of sustainable management and recycling [1]. Electronic waste is the fastest growing waste stream. At the same time, there are only five top-of-the line facilities in the world that can recycle e-waste with minimal release of dioxins. The sustainability of the design, production, and consumption of ICT should therefore be perceived as a priority in tackling e-waste.

This IFIP Position Paper – work on which began in Autumn 2017 - sets out some of the detail of the problem, as it currently stands, and what role the International Federation for Information Processing affirms it can play in trying to redress it.

2 - Definition and scope

The principal areas of concern for this Position Paper are electronic waste and sustainable development. Electronic waste or e-waste is the term used to describe discarded electronic and electrical equipment (EEE) that is not reused, repaired or refurbished. In other words, discarded EEE whose components are recycled in some form or that is simply dumped in a landfill. The StEP Initiative has defined electronic waste as follows: "E-Waste is a term used to cover items of all types of electrical and electronic equipment (EEE) and its parts that have been discarded by the owner as waste without the intention of re-use." [2]. While the term e-waste covers also non-ICT equipment, we will continue to use the term e-waste in this Paper.

Sustainability is the term used by the United Nations to describe all activity that meets the needs of the present without compromising the ability of future generations to meet their own needs [3]. Goal 12 of the United Nations Sustainable Development Goals (SDGs), to 'Ensure sustainable consumption and production patterns' [4], Goal 8, to 'Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all,' and Goal 9, to 'Build resilient infrastructure, promote sustainable industrialization and foster innovation,' are the most relevant to the problem of e-waste and sustainability. The most relevant of the 169 individual targets of the UN Sustainable Development Goals are two of Goal 12's targets: 'By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse,' and 'Encourage companies, especially large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle.' Also, one of Goal 9's targets is relevant: 'By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities.' [5].

Beyond these Sustainable Development Goals are increasingly strong voices reminding us that we live on a finite planet. Researchers in Earth Science have developed a framework that presents the planetary limits within which humanity can thrive. This Planetary Boundaries framework presents nine quantitatively established boundaries to human activity [6,7]. Crossing one or more boundaries can result in abrupt, non-linear and irreversable environmental change. Economist Kate Raworth has added a Social Foundation, roughly compatible to the Sustainable Development Goals, to these planetary boundaries, consisting of twelve dimensions that form the essentials of human life [8]. The space within the ecological foundation, formed by the planetary boundaries, and the social foundation is the "safe and just space for humanity" [9]. Sustainability can thus be understood as "securing the social foundation for people everywhere now and in the future, while staying within planetary boundaries" [10]. The centrality of planetary issues is also reflected in the most recent Global Risks Report by the World Economic Forum [11], in which environmental risks dominate. Climate change, and the failure to address it, biodiversity loss and ecosystem collapse, and man-made environmental disasters are seen as risks with a high likelihood and a high impact.

This Position Paper is focussed upon ICT products as a potential waste problem and how the ICT industry and ICT professionals can contribute to sustainability. The International Telecommunications Union (ITU) are engaging actively with other UN bodies and the World Economic Forum on this pressing issue [12], and IFIP believes it, too, can play a significant role in supporting the industry to overcome the problems associated with the unsustainabilities found in the end-of-life phase of ICTs.

Broadly, the role IFIP can play in regard to e-waste is envisaged in four primary streams:

(1) **Waste management:** Promote research towards systems development to help with waste management, and communication between producers and disposers;

(2) **Design:** Help to bring the problem to the attention of the IT industry, through publications, declarations, membership criteria, etc., focussed on the reality that many of the environ mental problems in ICT can be addressed only at 'design-time,' or 'by design.' Specifically, therefore, in order to:

  a. Prevent or postpone ICTs becoming e-waste through interventions in the design of ICTs that extend their lifespan, make them more reparable (Design for repairability), and improve their recyclability (End-of-life design)

  b. Make e-waste non-toxic through interventions in the design of ICTs - e.g. by developing and using less hazardous materials

(3) **Economics:** Encourage more creative economic thinking, similar to the 'circular economy' ambitions of the EU (see below), and other sustainable business models

(4) **Policy:** Contribute to the development of policies that regulate the design (e.g. EU's Eco-Design Directive), repair, and management of discarded ICTs

Additionally, this Position Paper calls for contributions from the IFIP community towards the possibilities of an IFIP E-Waste Control Certification scheme, or Badges, and such mechanisms by which IFIP might promote fairer, cleaner, and greener ICT across the industry.
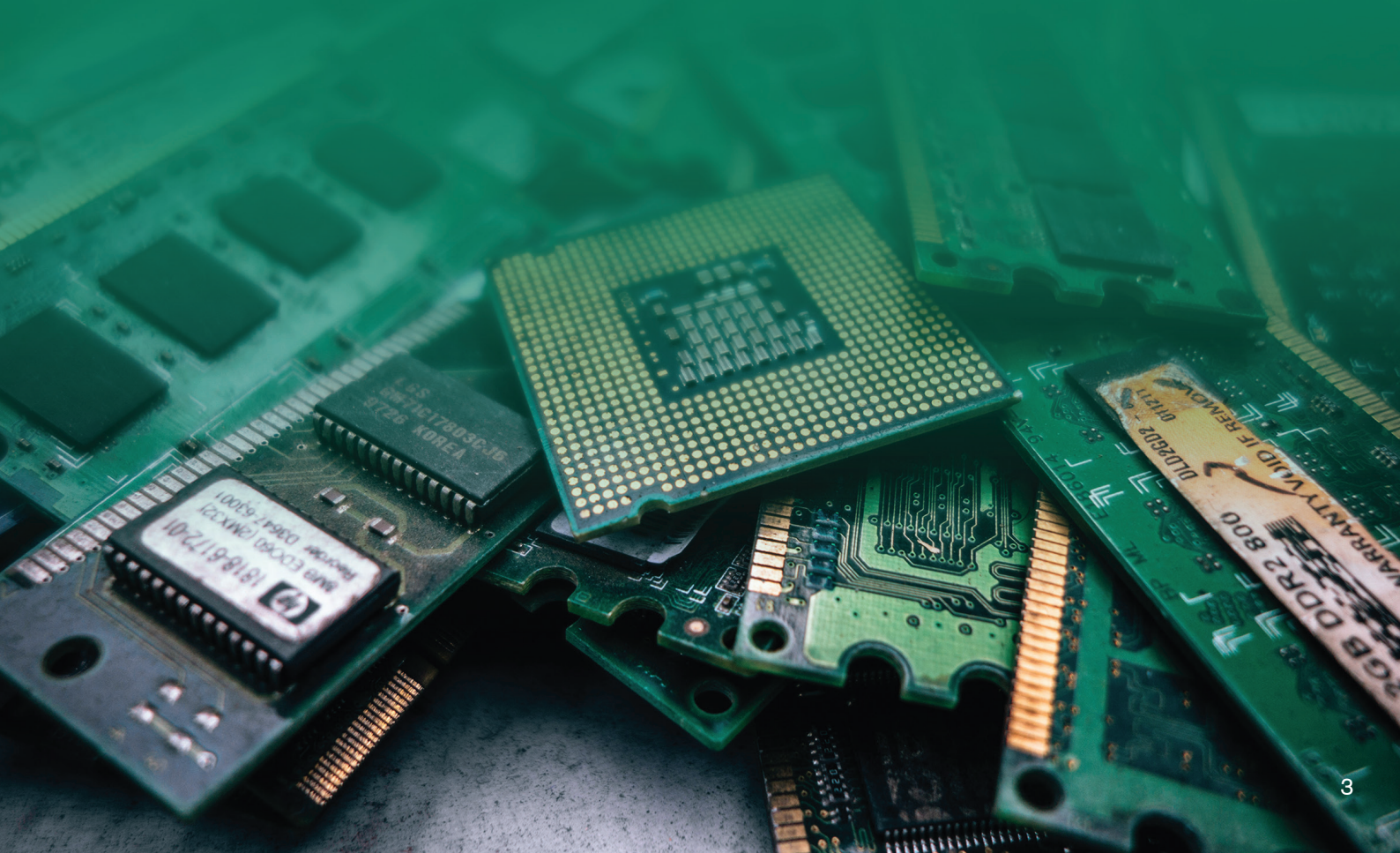
3 - The Global E-Waste Problem

E-waste is a growing global problem and the last decades have brought several new initiatives and regulations. The latest Global E-Waste Monitor calculated that in 2016, "the world generated 44.7 million metric tonnes (Mt) of e-waste and only 20% was recycled through appropriate channels." [1]. The majority of the other 80% remains with the user [13], is thrown in residual waste (4%), is traded as second-hand goods, or is recycled under inferior circumstances.

There are several global policies regulating the transport and management of electronic waste. Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal came into place in 1992 and restricts the movement of hazardous waste from high-income to low-income countries [14]. Of the high-income countries, only the USA has not ratified the Convention. In 1995, the Basel Ban Amendment was proposed, which would ban all shipment from OECD countries to low-income

Wikipedia

countries, including export for recycling, but the Amendment is not ratified, because not enough countries support it. The European Union countries and Norway and Switzerland have fully implemented the Amendment in their national legislation [15].

The EU Waste Electrical and Electronics Equipment (WEEE) Directive from 2012 promotes the "re-use, recycling and other forms of recovery of waste electrical and electronic equipment (WEEE) in order to reduce the quantity of such waste to be disposed and to improve the environmental performance of the economic operators involved in the treatment of WEEE" [16].

As of 2018, two-thirds of countries are covered by a national e-waste management policy. [1]. Almost all national and international policies include a take-back system, often based on an Extended Producer Responsibility (EPR) clause, in which the producer or distributer is obliged to collect used electronic and electrical products for reuse and recycling. Even though "policymakers, producers and recyclers in various countries have created specialized 'take-back and treatment' systems to collect e-waste from final owners and process it in professional treatment facilities (...) the collection and state-of-the-art treatment of e-waste is limited, and most nations are still without such e-waste management systems." [17]. For example, the USA produced 6.3 Mt of e-waste in 2016, but only 1.4 Mt was collected (22%) and it is unknown what happened with the rest [1]. Earlier data show, however, how some 34% of all electronic goods produced in the US in 2010 ended up in landfills, and a total of 8.5% (some 50,000 MT) was exported [18]. The country producing the largest amount of e-waste per capita in the world is Norway (28,5 kg per inhabitant), but it has also one of the highest collection rates (49,2%) [1]. Only five countries in the world (Belgium, Canada, Germany, Japan, Sweden) have smelters for copper and precious metals recovery that are equipped to minimise the release of doxins [19].

One complicating factor is that what is considered e-waste in one place, is considered reusable electronics in another. Large amounts of electronic equipment are replaced every year; not because they are broken, but because of depreciation (accounting), lack of updates, need of repair or new models entering the market. Such "e-waste" is often shipped as second-hand goods to low-income countries, where it is considered an important resource [20]. About 70% of these goods are still functioning and are immediately sold on to local second-hand markets. The rest is repaired and sold or ends up at local scrap yards. The lack of sustainable e-waste management results in widescale environmental impacts as well as health impacts to the people and communities working in or living near these sites [e.g. 21, 22, 23, 24].

In addition, illegal trade in e-waste still continues because of problems with enforcement of legislation at both sides of these trade routes [25]. Filling second-hand cars, which can be legally traded, with e-waste, or falsifying documents, are some of the methods used in the illegal trade [26]. Another factor is WEEE legislation, which has resulted in higher costs for sustainable e-waste management. For example, it is 10 times cheaper to export e-waste to China than to process it in the USA [25].

Wikipedia

4 - A Systems Perspective to a Complex Problem

Perhaps the most difficult aspect of this growing problem is its complexity. Microprocessors in the 1980s incorporated as little as twelve chemical elements. Contemporary processors require some 60 elements – "more than half of all existing elements on earth" [27]. A breakdown of the problem into its constituent parts reveals a combination of interdependent issues, from design that results in short lifespans, the depletion of the resources needed to manufacture electronic devices, and the issues surrounding electronic waste already discussed above.

Planned obsolescence is still a central problem in the electronics sector. Goods are designed to shorten, rather than to extend their lifespan. For example, most latest model smartphones are glued, rather than screwed together, making it difficult and expensive to replace the battery. Battery management is both hardware and software-based and can be designed to provide only a certain amount of charge cycles. Diminished battery capacity is one of the main reasons for people to buy a new smartphone [28]. Also the use of pentalob screws in computers and mobile phones prevents repair and thus may shorten the lifespan [29]. The lifespans of electronics are generally falling [30,31].

Resource depletion is a growing problem for many industries. As the global population rises, and the economic model of GDP growth encourages constant innovation, the use of resources is increasing rapidly. This includes the depletion of metals, such as gold, aluminium and what are commonly referred to as Rare Earth Minerals [32,33,34,35,36], which are central to the production of ICTs. The recycling of e-waste, for the recovery of these minerals (urban mining), is thus a central concern for the electronics industry.

The recycling of electronic waste is in many places in the world an informal economic activity and is often based on recovering the most profitable parts or metals and burning or dumping the rest. Informal recycling of e-waste provides income to millions of scavengers, disassemblers, and traders, but it is the same informality that prevents more sustainable work practices. In formal recycling, top-of-the-line facilities recycle the whole device, recovering a large amount of metals, while using the rest as fuel for the smelter. Other facilities often shred e-waste - because it is more cost-effective - and either melt it down - using it as feedstock in steel making operations - or simply bury it in landfill. In both cases, materials and energy are lost and, needless to say, these practices merely add to the problems of resource depletion and the pollution of the environment.

Any attempt to address the issue of electronic waste and sustainability needs to consider the interdependence of the different aspects of the issue as discussed above: design, resource depletion, environmental degradation, and human health impacts. For example:

▎ Design for repairability can extend the lifespan of ICTs through plug-and-play upgrades and improvements, both hardware and software [37], as well as a modular design that encourages repair [38].

▎ End-of-life design results in a less complex disassembly process and less scrap [39].

The combination of Design for repairability and End-of-life design can contribute to a set of electronics design guidelines that meet circular economy principles [40]. In addition, a Best of 2 Worlds (Bo2W) approach, in which informal disassembly of electronics is combined with formal high tech recycling, may diminish health and environmental impacts [41].

5 - IFIP's position on major questions and choices

This section of the position paper comprises a series of statements about choices that can be made and / or should be made in the light of the e-waste problem outlined above, and can be described as a "set of the right questions".

Faced with the enormity of the task, and the power of corporations and market forces, the most elementary choice facing individuals in the ICT industry is the question "what can I do?". The answer to this question is not straightforward. In the following paragraphs this and a number of other questions will be addressed. In each paragraph IFIP's position on a variety of aspects is presented and substantiated. We begin with the main actor, the ICT Industry:

5.1 - ICT Industry

Leaders in the ICT industry, and researchers working within the ICT industry, should take note that:

I. IFIP's position is that the ICT industry should move rapidly to adopt sustainability practices in line with the Planetary Boundaries and the UN Development Goals, in particular Sustainable Development Goals 8, 9 and 12.

    Such practices are a prerequisite for ICT industry actors to be considered sustainable.

II. IFIP's position is that the ICT industry should not design and develop devices and systems that over-use precious resources and that are destined to be rapidly discarded.

    Taking responsibility for the sustainability impact of devices and systems should be fundamental to ICT product design and ICT lifecycle design.

III. IFIP's position is that shifting from a linear economy, that assumes infinite and perpetual growth, to a circular economy, in line with the reality of planetary boundaries, must be a guiding and urgent principle for the ICT industry.

    Repair, re-use, and refurbishment of ICTs are central activities in a circular economy and preceed recycling of component materials.

5.2 - Authority / regulator

IV. IFIP's position is that policymakers / regulators should enforce the international policies that regulate electronic waste. For example, the Basel Convention and its Amendment Ban should be ratified globally and enforced rigorously, and policymakers should require companies to take responsibility for the take-back and disposal of their products, adopting the 'polluter pays' principle.

    In general, policymakers / regulators should introduce stricter guidelines, enforcing what are currently ambitions, goals and targets.

V. IFIP's position is that the EU's EcoDesign Directive should be extended to include ICTs such as computers, laptops, tablets, and mobile phones, providing design guide lines which will ensure their repairability, durability, energy use, and material use, and that comparative EcoDesign policies should be adopted worldwide.

Classification markers delineating a device's repairability and use of non-hazardous materials should be introduced for laptops, smartphones, tablets, and other electronic devices.

VI. IFIP's position is that in order to prevent the rapid disposal of ICTs, new legislation is needed to extend consumer rights and to secure the availability of spareparts and software upgrades for a reasonable time.

New consumer legislation in France, the so-called Hamon Law, stipulates that a company found to be deliberately shortening the life of its products can be fined up to five percent of its annual sales while executives can face up to two years in jail. IFIP recommends the adoption of similar legislation worldwide.

Where possible, consumers should be able to access and use repair information and spareparts to extend the lifespan of their equipment.

5.3 - ICT professional

VII. IFIP's position is that an ICT professional should have sufficient professional and environmental understanding to make the right choices when designing, developing, implementing, operating or managing software / hardware.

Having sufficient professional, social, and ethical understanding is a general requirement for ICT professionals. However, in the context of e-waste, this must (newly) include a range of additional responsibilities concerning the procurement, use, and disposal of hardware and software:

Procurement
- When procuring new hardware, a fair and sustainable value chain, expected use-life, producer warranty, upgradability, repair-ability, and sustainable recycling should all be factors in decision-making.

- When procuring software, the backward compatibility of future upgrades, energy use, ease of maintenance, and its adaptability to new platforms and uses should all be factors in decision-making.

Use
- Hardware should - where possible - be made to support extended use-life, rather than contribute to a rapid disposal and upgrade cycle. Care and maintenance of hardware to extend its life, through the long-term availability of spare parts and upgrading components are important strategies in supporting sustainable use.

- Software should – where possible – be made to conserve energy consumption, support extended use-life, and generally contribute to sustainable lifestyles.

End-of-life
> When use-life has come to an end, repair, reuse, and refurbishment should be considered before recycling.

An ICT professional may not be in a position to decide upon the design. This means that a condition for making this work is to have professional and environmental understanding not only embedded in the codes of ethics of societies of professionals but also in companies' policies. Further, it will be necessary to have a work environment that is supportive of putting these policies into practice with appropriate enforcement options.

VIII. **IFIP's position is that ICT professionals have an obligation to educate / inform users on issues concerning e-waste.**

Users should be informed about the resources used in a device, its longevity, and what will happen to it when its use-life is over. If the creator of such devices does not (sufficiently) inform the users, ICT professionals have a choice to do this, for instance via research papers and publications. In order to be able to do this, there should be no legal liability when publishing such results. Such information should be as clear as possible, avoiding opaque technicalities, for example, such as complex nutritional information on some food packaging.

5.4 - User

Both individuals and organizations can be in the role of a user.

IX. **IFIP's position is that users should be able to choose sustainable devices, and that they should be conversant with the resource use and end-of-life plan for whatever devices they purchase.**

X. **IFIP's position is that it supports the possibility to empower users in such a way that they can ensure all their devices are properly and ethically recyclable, make use of recycled resources, and do not contribute to environmental degradation.**

For example, if a mobile phone shop carries a range of devices from different companies, it should give the user clear information about the materials used in the device as well as the repairability and recyclability of the device and its 'take-back' arrangements, in a similar manner to the best examples of ingredients, nutrition, and other information on food products. This means that policies / regulations / legislation should require this.

XI. **IFIP's position is that involving users in the design and development of end-of-life schemes should be encouraged, to ensure recycling and disposal is ethically undertaken.**

Users need not only play a passive role because they are also often people who possess knowledge and can contribute to the design/development of resource-use and recycling in devices. Contributing to the design process would be one way to encourage their active participation. Open innovation and participatory design methodologies can be helpful and should be encouraged. Research that helps to bring users' perspectives into the design process should be particularly encouraged.

6 - Possible actions

IFIP, its member societies, and their members can positively contribute to the issues addressed above. What can be done:

- Check / promote the presence of professional and environmental.
  - in codes of ethics of professional societies
  - in companies' HR policies
- Provide a "set of the right questions" in your workplace.
- Promote the above position statements to the industry, authorities, professionals, and users.
- Increase research of those aspects of the e-waste problem and its potential solutions that are insufficiently addressed and / or that are gaining more and more importance.

7 - Annex. References and Bibliography

[1] Baldé, C. P., Forti, V., Gray, V., Kuehr, R., Stegmann, P (2017) The global e-waste monitor – 2017. United Nations University, IAS-SCUCLE, Bonn, Germany. Available from https://www.itu.int/en/ITU-D/Climate-Change/Documents/GEM%202017/Global-E-waste%20Monitor%202017%20.pdf

[2] StEP White Paper (2014) *One Global Definition of E-waste* Accessed from http://www.step-initiative.org/e-waste-challenge.html

[3] Brundtland Commission (1987) *Our Common Future: Report of the World Commission on Environment and Development* http://www.un-documents.net/our- common-future.pdf Para 27.

[4] https://www.un.org/sustainabledevelopment/infrastructure-industrialization/

[5] https://www.un.org/sustainabledevelopment/sustainable-consumption-production/

[6] Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F. S., Lambin, E., … Foley, J. (2009). Planetary Boundaries: Exploring the Safe Operating Space for Humanity. *Ecology and Society, 14*(2). Retrieved from http://www.jstor.org/stable/26268316

[7] Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., … Sörlin, S. (2015). Planetary boundaries: Guiding human development on a changing planet. *Science, 347*(6223), 1259855 https://doi.org/10.1126/science.1259855

[8] Raworth, K. (2012). A safe and just space for humanity: can we live within the doughnut. *Oxfam Policy and Practice: Climate Change and Resilience, 8*(1), 1–26. Retrieved from http://www.ingentaconnect.com/content/oxpp/oppccr/2012/00000008/00000001/art00001

[9] Raworth, K. (2017). *Doughnut Economics: Seven Ways to Think Like a 21st-Century Economist.* Chelsea Green Publishing.

[10] Structural Issues Associated with Regulating the Life Cycle of Products. (2018). In E. Maitre-Ekern, C. Dalhammar, & H. Bugge (Eds.), *Preventing Environmental Damage from Products: An Analysis of the Policy and Regulatory Framework in Europe* (pp. 21-150). Cambridge: Cambridge University Press.

[11] World Economic Forum (2019). The Global Risks Report 2019, 14th Edition. Geneva, Switserland. 114 pp.

[12] "A New Circular Vision for Electronics: Time for a Global Reboot" (2019) E-Waste Coalition https://www.itu.int/en/ITU-D/Climate-Change/Documents/2019/A-New-Circular-Vision-for-Electronics.pdf

[13] Wilson, Garrath T., Grace Smalley, James R. Suckling, Debra Lilley, Jacquetta Lee, and Richard Mawle. "The Hibernating Mobile Phone: Dead Storage as a Barrier to Efficient Electronic Waste Recovery." *Waste Management*, Special Thematic Issue: Urban Mining and Circular Economy, 60 (February 1, 2017): 521–33. https://doi.org/10.1016/j.wasman.2016.12.023.

[14] http://www.basel.int/TheConvention/Overview/TextoftheConvention/tabid/1275/Default.aspx

[15] Rucevska I., Nellemann C., Isarin N., Yang W., Liu N., Yu K., Sandnæs S., Olley K., McCann H., Devia L., Bisschop L., Soesilo D., Schoolmeester T., Henriksen, R., Nilsen, R. 2015. *Waste Crime – Waste Risks: Gaps in Meeting the Global Waste Challenge.* A UNEP Rapid Response Assessment. United Nations Environment Programme and GRID-Arendal, Nairobi and Arendal, www.grida.no p.11.

[16] Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE) https://eur-lex.europa.eu/eli/dir/2012/19/oj

[17] Balde, C.P., Wang, F., Kuehr, R., Huisman, J. (2015). The global e-waste monitor – 2014. United Nations University, IAS-SCUCLE, Bonn, Germany. Available from https://i.unu.edu/media/unu.edu/news/52624/UNU-1stGlobal-E-Waste-Monitor-2014-small.pdf

[18] CEC. (2016) *Quantitative Characterization of Domestic and Transboundary Flows of Used Electronic Products. Case Study: Used Computers and Monitors in North America.* Montreal, Canada: Commission for Environmental Cooperation. Accessed from http://www3.cec.org/islandora/en/item/11673-quantitative-characterization-domestic-and-transboundary-flows-used-electronicp. 12

[19] Liddick, D. R. (2011). *Crimes Against Nature: Illegal Industries and the Global Environment.* Santa Barbara, Calif: Praeger.

[20] Lepawsky, Josh, Erin Araujo, John-Michael Davis, and Ramzy Kahhat. "Best of Two Worlds? Towards Ethical Electronics Repair, Reuse, Repurposing and Recycling." *Geoforum 81* (May 2017): 87–99. https://doi.org/10.1016/j.geoforum.2017.02.007

[21] Asamoah, Anita, David Kofi Essumang, Jens Muff, Sergey V. Kucheryavskiy, and Erik Gydesen Søgaard. "Assessment of PCBs and Exposure Risk to Infants in Breast Milk of Primiparae and Multiparae Mothers in an Electronic Waste Hot Spot and Non-Hot Spot Areas in.

[22] Grant, Kristen, Fiona C Goldizen, Peter D Sly, Marie-Noel Brune, Maria Neira, Martin van den Berg, and Rosana E Norman. "Health Consequences of Exposure to E-Waste: A Systematic Review." *The Lancet Global Health* 1, no. 6 (December 1, 2013): e350–61. https://doi.org/10.1016/S2214-109X(13)70101

[23] Li, Huiru, Mark J. La Guardia, Hehuan Liu, Robert C. Hale, T. Matteson Mainor, Ellen Harvey, Guoying Sheng, Jiamo Fu, and Ping'an Peng. "Brominated and Organophosphate Flame Retardants along a Sediment Transect Encompassing the Guiyu, China e-Waste Recycling Zone." *Science of The Total Environment* 646 (January 1, 2019): 58–67. https://doi.org/10.1016/j.scitotenv.2018.07.276

[24] Awasthi, Abhishek Kumar, Xianlai Zeng, and Jinhui Li. "Environmental Pollution of Electronic Waste Recycling in India: A Critical Review." *Environmental Pollution* 211 (April 1, 2016): 259–70. https://doi.org/10.1016/j.envpol.2015.11.027

[25] https://efface.eu/sites/default/files/EFFACE_Illegal%20shipment%20of%20e%20waste%20from%20the%20EU.pdf

[26] Odeyingbo, Olusegun, Innocent Nnorom, and Otmar Deuzer. "Person in the Port Project: Assessing the Import of Used Electronic Equipment into Nigeria." Bonn: United Nations University, 2018.

[27] Löser, F., 2015. *Strategic information systems management for environmental sustainability: enhancing firm competitiveness with Green IS* (Vol. 6). Universitätsverlag der TU Berlin.

[28] https://www.statista.com/statistics/716163/reasons-for-buying-a-new-smartphone-in-the-us/

[29] https://en.wikipedia.org/wiki/Pentalobe_security_screw

[30] Wieser, Harald. "Beyond Planned Obsolescence: Product Lifespans and the Challenges to a Circular Economy." GAIA - *Ecological Perspectives for Science and Society* 25, no. 3 (January 1, 2016): 156–60. https://doi.org/10.14512/gaia.25.3.5

[31] Bakker, Conny, Feng Wang, Jaco Huisman, and Marcel den Hollander. "Products That Go Round: Exploring Product Life Extension through Design." *Journal of Cleaner Production* 69 (April 15, 2014): 10–16. https://doi.org/10.1016/j.jclepro.2014.01.028.

[32] Krugman 2010 https://www.nytimes.com/2010/10/18/opinion/18krugman.html

[33] Humphries 2013 www.crs.gov

[34] Jolly 2014 https://www.nytimes.com/2014/03/27/business/international/china-export-quotas-on-rare-earths-violate-law-wto-panel-says.html?_r=0

[35] Ferris 2015 https://www.eenews.net/stories/1060011478

[36] WSJ 2016 https://www.wsj.com/articles/chinas-rare-earths-bust-1468860856

[37] http://sustainabilitydesign.org/karlskrona-manifesto/

[38] Cordella, M., Sanfelix, J., & Alfieri, F. (2018). Development of an Approach for Assessing the Reparability and Upgradability of Energy-related Products. *Procedia CIRP*, 69, 888–892. https://doi.org/10.1016/j.procir.2017.11.080

[39] Xing, K., Abhary, K., & Luong, L. (2003). IREDA: An Integrated Methodology for Product Recyclability and End-of-life Design. *The Journal of Sustainable Product Design*, 3(3), 149–171. https://doi.org/10.1007/s10970-005-3925-9

[40] Bovea, M. D., & Pérez-Belis, V. (2018). Identifying design guidelines to meet the circular economy principles: A case study on electric and electronic equipment. *Journal of Environmental Management,* 228, 483–494. https://doi.org/10.1016/j.jenvman

[41] Wang, F., Huisman, J., Meskers, C. E. M., Schluep, M., Stevels, A., & Hagelüken, C. (2012). The Best-of-2-Worlds philosophy: Developing local dismantling and global infrastructure network for sustainable e-waste treatment in emerging economies. Waste Management, 32(11), 2134–2146. https://doi.org/10.1016/j.wasman.2012.03.029

International Federation for Information Processing
Position Paper
E-Waste: taking responsibility
http://www.ifip.org/