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SERIES L: ENVIRONMENT AND ICTS, CLIMATE CHANGE, E-WASTE, ENERGY EFFICIENCY; CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

E-waste and circular economy

Guidance for institutions of higher learning to contribute in the effective life cycle management of e-equipment and e-waste

Recommendation ITU-T L.1033

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ENVIRONMENT AND ICTS, CLIMATE CHANGE, E-WASTE, ENERGY EFFICIENCY; CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

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Recommendation ITU-T L.1033

Guidance for institutions of higher learning to contribute in the effective life cycle management of e-equipment and e-waste

Summary

Managing e-waste has been a major problem in many countries. Emerging economies still face a multitude of challenges that hinder the effective management of e-equipment and e-waste. Many of them do not have suitable facilities to handle e-equipment and e-waste and have inadequate implementation frameworks and structures due to the lack of quantifiable data and statistics on e-equipment and e-waste, inadequate policies, regulations, standards and enforcement strategies, low stakeholder engagement/collaboration and limited expertise. Institutions of higher learning have a crucial role in leading society through its influence and the development of individuals. As societal issues become more complex and the boundaries between academia, industry, and the government become unclear, institutions of higher learning must remain the cornerstone of development. Universities among other higher learning institutions are better placed to ensure that the circularity of electrical and electronic equipment (EEE) is achieved to minimize the effects of waste electrical and electronic equipment (WEEE).

The role of universities as examples of institutions of higher learning, is to offer training, carry out research and share knowledge, ideas, research output and innovations developed and applied for its benefit and the surrounding communities. Universities have the capacity to develop a curriculum on life cycle-economy processes, including e-waste management, for formal training and material for informal and non-formal training. Universities can also join efforts to research and provide reliable information that can be used in policy formulation, development of standards and strategies on imports and exports to the region. Recommendation ITU-T L.1033 therefore aims to guide institutions of higher learning to collaboratively contribute on key aspects of managing e-resources and e-waste. It explores how these institutions can engage in EEE circularity by checking their effective involvement in every EEE and WEEE process.

History

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FOREWORD

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Introduction

Education is an essential tool in reshaping human values and has the enormous potential to address the sustainability challenges facing humanity. Education is also acknowledged as a means for achieving or inter-coordinating the SDGs [b-Koiupi 2019]. Since the core business industry of institutions of higher learning involve the development, dissemination of knowledge and learning, knowledge management is thus deemed as significant in the life cycle management of EEE as e-resources and e-waste.

The life cycle of equipment is a relatively new concept brought about by innovation and technology. Since it is a relatively new concept, much research, training and engagement within communities are required. Government ministries and agencies have endeavoured to come up with strategies, guiding principles and other legal instruments however they still lack the basis for the implementation of these documents owing to unreliable documented information to support the decisions made. For example, data on imports and exports remains insufficient, and countries might not know or may even not report how much electrical and electronic equipment is acquired and how much raw materials and e-wastes are generated annually [b-UNCTAD 2019]. Many countries are also struggling with how extended producer responsibilities (EPR) and take-back systems must be handled, due to this there is a huge need for designing procedures for the collection of e-waste and the development of technology for recycling, repair, etc.

Creating awareness and sensitizing the public towards effective and sustainable management of EEE at the end of life comes with the challenges of "how effective the communication is". Higher institutions of learning present advantages of adequate awareness through well-thought procedures, research and surveys and cost effectiveness.

As people buy and consume EEE, scholars must be at the forefront in advising governments, contributing to the development of policies, guiding principles and developing standards and training programmes. They should also advice other stakeholders on how to properly handle e-waste. Importantly, as part of its legal mandate, institutions of higher learning (IHL) are in the position to conduct research on quantities, carry out statistical measures, develop knowledge and methods to identify and manage e-resources and e-waste in their countries and regions.

Recommendation ITU-T L.1033

Guidance for institutions of higher learning to contribute in the effective life cycle management of e-equipment and e-waste

1 Scope

This Recommendation establishes guidance for institutions of higher learning to collaboratively contribute on key aspects of managing e-resources and e-waste. It explores how institutions of higher learning can engage in EEE circularity by checking its effective involvement in every EEE and WEEE process.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T L.361] Recommendation ITU-T L.361/L.64 (2012), *ID tag requirements for infrastructure and network elements management*.

[ITU-T L.1010] Recommendation ITU-T L.1010 (2014), *Green battery solutions for mobile phones and other hand-held information and communication technology devices*.

[ITU-T L.1015] Recommendation ITU-T L.1015 (2019), *Criteria for evaluation of the environmental impact of mobile phones*.

[ITU-T L.1020] Recommendation ITU-T L.1020 (2018), *Circular economy: Guide for operators and suppliers on approaches to migrate towards circular ICT goods and networks*.

[ITU-T L.1021] Recommendation ITU-T L.1021 (2018), *Extended producer responsibility – Guidelines for sustainable e-waste management*.

[ITU-T L.1022] Recommendation ITU-T L.1022 (2019), *Circular economy: Definitions and concepts for material efficiency for information and communication technology*.

[ITU-T L.1023] Recommendation ITU-T L.1023 (2020), *Assessment method for circular scoring*.

[ITU-T L.1024] Recommendation ITU-T L.1024 (2021), *The potential impact of selling services instead of equipment on waste creation and the environment – Effects on global information and communication technology*.

[ITU-T L.1030] Recommendation ITU-T L.1030 (2018), *E-waste management framework for countries*.

[ITU-T L.1032] Recommendation ITU-T L.1032 (2019), *Guidelines and certification schemes for e-waste recyclers*.

[ITU-T L.1100] Recommendation ITU-T L.1100 (2012), *Procedure for recycling rare metals in information and communication technology goods*.

[ITU-T L.1400] Recommendation ITU-T L.1400 (2011), *Overview and general principles of methodologies for assessing the environmental impact of information and communication technologies*.

[ITU-T L.1410] Recommendation ITU-T L.1410 (2014), *Methodology for environmental life cycle assessments of information and communication technology goods, networks and services*.

[ITU-T L.1420] Recommendation ITU-T L.1420 (2012), *Methodology for energy consumption and greenhouse gas emissions impact assessment of information and communication technologies in organizations*.

[ITU-T L.1430] Recommendation ITU-T L.1430 (2013), *Methodology for assessment of the environmental impact of information and communication technology greenhouse gas and energy projects*.

[ITU-T L.1440] Recommendation ITU-T L.1440 (2015), *Methodology for environmental impact assessment of information and communication technologies at city level*.

[ITU-T L.1450] Recommendation ITU-T L.1450 (2018), *Methodologies for the assessment of the environmental impact of the information and communication technology sector*.

[ITU-T L.1460] Recommendation ITU-T L.1460 (2018), *Connect 2020 greenhouse gases emissions – Guidelines*.

[ITU-T L.1470] Recommendation ITU-T L.1470 (2020), *Greenhouse gas emissions trajectories for the information and communication technology sector compatible with the UNFCCC Paris Agreement*.

[ITU-T L.1500] Recommendation ITU-T L.1500 (2014), *Framework for information and communication technologies and adaptation to the effects of climate change*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 circular economy [ITU-T L.1022]: Covers the full life cycle of both goods and business models. In general it is about closing the loop between different life cycles through design and corporate actions/practices that enable recycling and reuse in order to use raw materials, goods and waste more efficiently and to increase energy performance.

3.1.2 circularity [b-MCART 2020]: Designing out waste and pollution, keeping products and materials in use, and regenerating natural systems.

3.1.3 e-waste [b-ITU-T L.1031]: Electrical or electronic equipment that is waste, including all components, sub-assemblies and consumables that are part of the equipment at the time the equipment becomes waste. The term e-waste and waste electrical and electronic equipment (WEEE) are used interchangeably.

3.1.4 ID tag [b-ITU-T Y.2213]: A physical object which stores one or more identifiers and optionally application data such as name, title, price, address, etc.

3.1.5 linear economy [ITU-T L.1022]: Cradle-to-grave; the 'take-make-waste' model; that is, extracting, manufacturing, using and wasting.

3.1.6 sustainable development [b-UN 1987]: Development that meets the needs of the present without compromising the ability of future generations to meet their needs.

3.1.7 tag-based identification [b-ITU-T Y.2213]: The process of specifically identifying a physical or logical object from other physical or logical objects by using identifiers stored on an ID tag.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 electronic resource: Electrical or electronic equipment (EEE), part, or component that can produce benefits from usage for a purpose or by a person.

NOTE – Defined in contrast to unwanted or unusable EEE that is e-waste.

3.2.2 institutions of higher learning: Institutions that offer an optional final stage of formal learning after secondary education.

NOTE 1 – These are often delivered at universities, academies, colleges, seminaries, conservatories, and institutes of technology, and through certain college-level institutions, including vocational schools, trade schools, and other career colleges that award academic degrees or professional certifications.

NOTE 2 – Adapted from [b-Heduc 2019].

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

CRT	Cathode Ray Tube
EEE	Electrical and Electronic Equipment
EIT	European Institute of Innovation and Technology
EPR	Extended Producer Responsibility
ESD	Education for Sustainable Development
ESM	Environmentally Sound Management
GHG	Greenhouse Gases
ICT	Information Communication Technology
IHL	Institutions of Higher Learning
KIC	Knowledge and Innovation Community
LCA	Life Cycle Assessment
LCD	Liquid Crystal Display
LERU	League of European Research Universities
MOOC	Massive Open Online Courses
NFC	Near Field Communication
PCB	Print Circuit Board
PPE	Personal Protective Equipment
QR	Quick Response
RAM	Random Access Memory
RFID	Radio Frequency Identifier Device
SRI	Sustainable Recycling Industries
SDG	Sustainable Development Goals

VAT	Value Added Tax
WEEE	Waste EEE or Waste Electrical and Electronic equipment
WRF	World Resources Forum
e-waste	electrical and electronic waste
e-resource	electrical and electronic resource
e-equipment	electrical and electronic equipment

5 Conventions

None.

6 The challenges of electronic and electrical equipment and electrical and electronic waste

Electrical and electronic equipment (EEE) is composed of diverse materials, and these natural resources are purchased, used and disposed of when no longer suitable for a purpose. They can be repaired, refurbished or remanufactured, reused for another purpose by another user and their parts can be reused too, but in the end, it becomes e-waste or WEEE, and potentially a source of secondary raw materials for new devices. In contrast to the 'take-make-waste' model of the linear economy, the circular economy aims to keep EEE as useful e-resources for as long as possible, in their highest utility and minimize waste [b-ITU-T L-Sup.28]. Among all the EEE, information communication technology (ICT) devices exhibit a clear potential for a circular lifespan. ICT devices tend to have a wider or even general purpose with the ability to repurpose through capabilities for device reconfiguration, hardware modularity, or software reprogramming. This wider suitability results in the ability to repair, reuse and upgrade products to facilitate reuse, [ITU-T L.1022] that may or may not be that easy or feasible in specialized, specific-purpose, non-reconfigurable EEE. This can help to achieve the ambitious environmental footprint impact reduction required for climate change mitigation [ITU-T L.1470]. For this reason alone, despite being applicable to all EEEs there is a focus on ICT devices, or digital devices, due to their potential to bring added value to the environment and the towards circular economy [ITU-T L.1022].

EEE is composed of various components, i.e., hazardous and non-hazardous materials. Components such as lead (Pb) and mercury (Hg) contaminate the soil and water when disposed of in the landfills with other wastes. These hazardous components (inorganic lead compounds and methylmercury compounds) are also listed, respectively, as probable (group 2A) and possible (group 2B) human carcinogens [b-WHO 2021]. They also damage the lungs and liver when eaten, ingested or inhaled. Improper management of WEEE poses an environmental and human health threat. These contaminated sources affect the growth of plants and aquatic life and have the potential to cause adverse health effects to humans. Primitive recycling and incineration of components for material recovery also produces toxic fumes which may contain certain persistent organic pollutants which pollute the atmosphere and contribute to greenhouse gases (GHG) emissions, as well as sludge from melting processes that contaminate soil and water.

6.1 E-equipment management challenges

Solutions are required not only at the instant of disposal of the e-waste but are required to be developed bearing in mind a broader **life-cycle thinking**, back at the source of materials, design, manufacturing, procurement, and usage. Since, e-waste is x-times the result of a linear "take, make, use, dispose" model, the circular economy models can be improved by keeping all the devices (e-equipment) as useful e-resources (devices, parts) thereby reducing or ideally eliminating e-waste. In any case, after a shorter or longer lifespan, e-equipment needs to be recycled to extract secondary materials or it is dumped in a landfill. Circularity is the keyway to move forward [b-GISWatch 2020].

The context is about sustainable development [b-UN 1987], and the achievement of the sustainable development goals (SDGs) depends on addressing the societal and environmental challenges: "*A universal call to action to end poverty, protect the planet and ensure that all people enjoy peace and prosperity by 2030."* [b-UNDP].

The diagram in Figure 1 is a visual framework for sustainable development – shaped like a doughnut or a lifebelt – combining the concept of planetary boundaries with the complementary concept of social boundaries [b-Raworth 2012]. The central circle of the model depicts the proportion of people that lack access to life's essentials (healthcare, education, equity and so on) while the crust represents the ecological ceilings (planetary boundaries) that life depends on and must not be overshot.

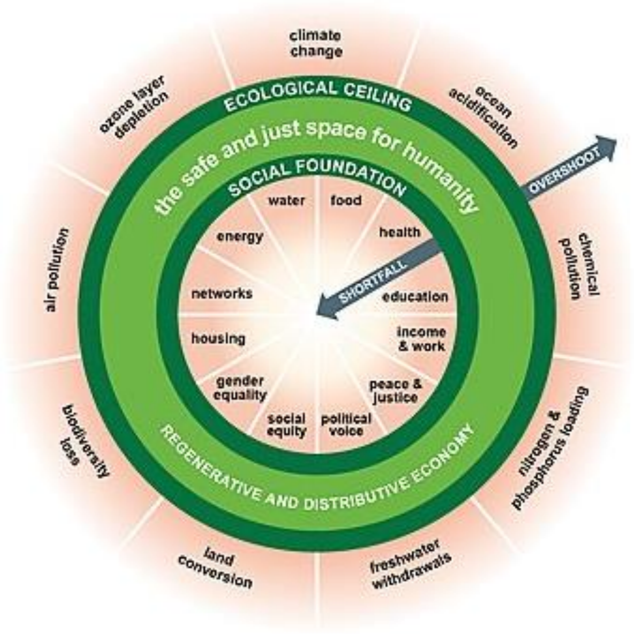

Figure 1 – Doughnut economics (Source: [b-Raworth 2012])

Therefore, there is a need to address environmental, economic and societal needs for a sustainable future, but we also have to ensure open ways to participate by considering the locations. There is a feasibility region within the planetary and social boundaries, that is also seen as economically viable.

6.2 E-waste management challenges

Globally, only 17.4 % of e-waste is documented to be formally collected and recycled [b-FOR 2020]. Monitoring the quantities and flows of e-waste is essential for evaluating developments of sound policies and legal instruments and can only be achieved with better e-waste data. Having better e-waste data is also essential to measure progress towards the global target set in 2018 at the International Telecommunication Union plenipotentiary conference of increasing the global e-waste recycling rate to 30 % by 2023. At a national level, harmonized and coherent e-waste data contributes to estimating the magnitude of challenges relating to e-waste, setting appropriate collections and recycling targets, establishing priorities for policy makers, influencing regulations, setting policy targets, and lastly allocating adequate financial resources [b-FOR 2020].

Developing countries and emerging economies have numerous e-waste management challenges to deal with. The challenges include lack of national legislation to manage and guide the management of e-waste, insufficient infrastructure and technology for treating e-waste, poor disposal methods and overreliance on the informal sector in the management of e-waste, lack of statistical data to inform on policies, improper handling of e-waste and lastly insufficient capacity building and awareness.

Many developing countries also have no suitable facilities to handle e-waste. The few available facilities are not able to process all e-waste components hence, they ship the hazardous components to Europe and Asia for further treatment [b-Basel 1989]. Extended producer responsibility (EPR) and take-back schemes, modern infrastructures and technologies for recycling are either non-existent or partially implemented. Handling of e-waste is characterized by manual stripping to remove electronic boards for resale, open-burning of wires to recover few materials, and the deposition of other bulk components, including cathode ray tubes (CRTs), in open dumpsites. These practices by the informal sector often involve the use of minors who lack the personal protective equipment (PPE) required for this kind of work. Developing countries have the least number of direct manufacturers of EEE, yet they carry a significant burden to the global e-waste problem.

7 The role of institutions of higher learning

The fundamental functions of institutions of higher learning are teaching and research, in addition to having the responsibility towards a wider society and supporting the communities in which they are embedded [b-UNESCO 2020]. In their teaching activities, universities provide the professional training as well as the education necessary for the development of a person. Furthermore, they carry out research to increase the body of theoretical knowledge as well as its application to practical problems.

7.1 Why institutions of higher learning?

Institutions of higher learning (IHL) combine the unique capabilities, activities, and the number of EEE devices they use and procedures to handle them, all this together when combined can have a traction effect within a country. In addition, given the difficulty or unfeasibility to transpose knowledge, procedures, practices and results from other world regions and economies, IHL are adaptive organizations capable of learning, choosing and adapting good practices elsewhere to the local conditions. These include developing methods and capabilities by ensuring that global objectives translate into adapted and feasible local ways, being able to propose local incentives, realize local benefits to ensure effective collective action towards maximizing the benefits of e-equipment and lastly minimizing the impact of e-waste and environmental impacts in general [b-Ostrom 2009].

Furthermore, in a competitive global economy, emerging economies suffer from external pressures that requires internal regulatory measures to protect their people, nature and economic activities, while they engage in a transformation to become "knowledge economies". *"Universities and other higher learning institutions have a role to play in this transformation, both as generators of new knowledge as well as actors that can interact with the local industry and contribute to its innovativeness."* [b-Giuliani 2012] Transformations can accelerate, as researchers can tap into international science results in diverse areas. They are or have the potential to be prepared to experiment, adapt and adopt, and transfer knowledge and its application to local students, industries, professionals and governments.

IHL can be complex institutions that require internal policies that can be a playground to test and develop its own experience as a consumer of EEE and generator of WEEE. The resulting practices and policies can be scaled up to other organizations and larger regions naturally, either by direct engagement with governments or indirectly through knowledge and experience of graduated students that join other public or private organizations and contribute to replicate these models, or those that create new innovative enterprises.

For these reasons, IHL can take a leading role in different countries and specifically in emerging economies in training, developing policies, carrying out research to quantify the number of devices produced or imported, in use and e-waste generated in their region. These include designing and developing new prototype products that are eco-friendly, developing new techniques and appropriate technologies for handling refurbishment or e-waste processing, and engaging with communities to sensitize them on the proper and efficient usage and disposal of EEE. Institutions of higher learning presumably have the ability to access funds and grants for research, have the capacity to carry out studies and are objective in the analysis of the different processes of the circular economy.

Given their academic role, IHL can act as neutral stakeholders as they are neither policy makers, nor manufacturers. The inherent capabilities of IHL translate towards several areas of action with unique contributions that are detailed in the next section, with a summary of Recommendations in clause 8.

8 Actions by the institutions of higher learning

The actions by IHL presented below are divided as organizational decisions (environmental and social responsibility policies, incentives and goals), as each main IHL function (training, research, transfer, public awareness), as well as the required engagement of IHL in the circular processes of their own digital devices (e-equipment, EEE).

The ITU connect 2030 agenda [b-ITUC 2018], which aims to achieve the five bold goals of growth, inclusiveness, sustainability, innovation, and partnerships, provides a framework for the aims and activities for action in IHL related to ICT technology and its role, and how IHL can engage and contribute to achieving these aims within their regions of influence and countries. All EEE and WEEE related actions should be framed within the international agreements signed by the countries to which IHL belong, as well as within the framework of the applicable national legislation.

8.1 Environmental and social responsibility policies, incentives and goals

The goals of the IHL organizations relate to all the UN SDGs and specifically to: Goal 4: Quality education; Goal 5: Gender equality; Goal 8: Decent work and economic growth; Goal 9: Industry, innovation and infrastructure; Goal 11: Sustainable cities and communities; Goal 12: Responsible production and consumption; and Goal 17: Partnerships for the goals.

For instance, the University of Leeds [b-Leeds] shows a commitment to embed the three pillars of sustainability [b-UN 2005] (economic, social and cultural, environmental) in every aspect by drawing from the expertise of students, staff and partners to collaborate in finding sustainable solutions to global challenges. In addition to reports on environmental impact and sustainability, the university follow a living lab approach to find and test real life solutions to global challenges, which aligns with their research, curriculum and operation, and are socially committed to having a positive impact on their local, national and global societies, by implementing the results of their experience everywhere.

Compliance with [ITU-T L.1470] in terms of GHG emission trajectories for the ICT sector requires technological advances, well-prepared people and adequate policies to accelerate the achievement of the United Nations sustainable development goals (SDGs) by 2030.

8.1.1 Zero carbon emissions and zero waste targets

Carbon neutrality implies the reduction of emissions and compensates through established mechanisms that cannot be reduced and/or absorbed. Since different universities adhere to global initiatives and/or standards, they adopt specific mechanisms for implementation. There is a need to translate global commitment to environmental impact, implementation of the Paris agreement, and the specific goals of [ITU-T L.1470] for the ICT sector into mechanisms / processes for implementation. For this purpose, universities have to create actionable policies that help to accelerate research capabilities into action, not just by adopting, but adapting and contributing in unique and innovative ways. Some examples are as follows:

The University of Leeds in the United Kingdom of Great Britain and Northern Ireland (UK) aims to reach zero carbon and zero waste by 2050 as mentioned in their annual sustainability report [b-Leeds 2020].

The University of Cambridge in the UK [b-CAM 2015] has a zero carbon target aligned with the 1.5ºC goal and to *"reduce energy related carbon emissions to absolute zero by 2048"*. The university's environmental sustainability vision, policy and strategy contain an aim to make a positive impact through outstanding environmental sustainability performance, that includes working with the municipality, hence benefitting the community.

The University of Cape Town in the Republic of South Africa (RSA) has set goals for its campuses for achieving net zero carbon, energy, water and waste-to-landfill by 2050. *"A key component to this strategy is enabling the campus to become a Living Lab for our students and staff as we work towards these transformative goals."* [b-UCT 2020].

The smart campus cloud network, coordinated by the TERRE policy centre in India has initiated an action under the programme supported by the UNESCO of making university campuses net zero carbon emission (Carbon neutral campus) [b-Shendre 2019].

Among others, the EEE and specifically ICT policies in IHL such as green procurement, maintenance and disposal including reuse and e-waste are an integral part towards becoming "zero carbon" or "zero waste" institutions as described below.

8.1.2 Instruments to achieve environmental and social responsibility

There are tools to manage the environmental responsibilities of IHL and other organizations like the [b-ISO 14000] family of environmental management systems.

Sustainable procurement is one of the important policies and strategies. The University of Cambridge (UK) announced in 2019, a science based target [b-CAM 2019], to reduce energy related carbon emissions to absolute zero by 2048 with an aspiration to achieve this by 2038. This translates into meeting the ISO 20400 standard for sustainable procurement [b-ISO 20400], so that purchases have *"the most positive environmental, social and economic impacts possible over [their] entire lifecycle."*

8.1.3 Environmental impacts: externalities, transparency and accountability

Environmental impacts that can be shifted to other organizations (externalities) must be accounted for, such as the excessive contribution to e-waste by recycling after the end of use in one organization. Choices can make a huge difference in social and environmental impacts, such as the preference for extended device lifespan through reuse (instead of premature recycling) with certification of final recycling, servitized usage models (computing as a service delivered to users, with computers owned by the service provider instead of the users) [ITU-T L.1024]. For instance, IHL institutions cannot buy the devices themselves but the services, so institutions will not have to manage the devices. Despite having some drawbacks, this option allows third parties to optimize the life span of the device.

Transparency and accountability policies can lead to producing yearly environmental impact reports, where EEE is a major contributor. These reports and the procedures to develop them by the IHL can become local models [b-Ostrom 2009] for training, research and easy transfer to society.

8.2 Education and training

Given the fundamental function of IHL in teaching and supporting communities, there are many different possibilities adapted to local conditions, with examples such as:

– Designing and offering training, certification on EEE management and e-waste recycling. appendix I shows the example of the Katholieke Universiteit Leuven (KU Leuven) in the Kingdom of Belgium (Belgium) towards the education of e-waste management through online courses.

– Students and staff training and vocational courses to raise awareness and promote good EEE practices that help minimize e-waste and its impact. This is the case of the TERRE initiative of the green olympics in India [b-TERRE 2019].

– Service learning combines learning objectives with community service to provide a pragmatic, progressive learning experience while meeting societal needs [b-Lopez 2015]. Learning can become an excellent exchange of experience and knowledge to bring practices outside of IHL organizations, and collect experiences to fine tune these processes, and improve their applicability. Appendix II shows the example of the Recyclotron e-waste collection initiative in the United Mexican States (Mexico), and [b-Lopez 2015] describes the computer reuse workshop at Universitat Politècnica de Catalunya (UPC) in Spain. [b-ITU-D 2018] presents the lessons learned from an experience at the National University of La Plata in the Argentine Republic (Argentina) with students and professors for the refurbishment and recycling of computers.

8.3 Research

The development of new knowledge, processes, and practices according to local, regional, national conditions to address and evolve the management of e-equipment and e-waste. This includes research-related activities on topics such as the following.

8.3.1 Scientific and technological research

In such a complex area, there are many diverse research topics where multiple disciplines can contribute. The following examples illustrate that:

– Engineering: Hardware design, including open-source hardware and "ecodesigns" including chips, mechanical drawings, schematics, bills of materials, print circuit board (PCB) layouts, released under free/libre terms. This allows the learning, analysis and improvements from the community, and facilitates maintenance, repair, upgrades, and therefore a longer lifespan.
– Software development, software tools and services to support green and circular economy processes, such as tools to support diagnostic, inventory, maintenance, accountability, and the generation of open datasets [b-Franquesa 2016].
– Life-cycle assessment (or life-cycle analysis) to assess environmental impacts of products.
– Material flow analyses of different e-equipment can provide the basis for estimating e-waste generation, and recycling rates, annually, at national level.
– Circular economy in general.
– E-waste prevention and processing methods considering quality, efficiency and auditability.
– Experimentation, like an experimental e-waste recycling workshop, or an experimental computer repair or preparation for reuse workshops, the development of local knowledge, improved methods and practices, such as those reported in [b-ITUDE 2018] [b-ITU-D 2018].

These activities can initialize experimenting and solving campus scale challenges and solutions, to scale them to their surrounding communities, regions and countries, leveraging from other IHL functions. Furthermore, IHL can benefit from collaboration with international collaborative initiatives with other IHLs, enterprises and other stakeholders, focused on emerging economies, e-waste management systems [b-SRI 2017] and the circular economy in general [b-DSG-UPC].

8.3.2 Research on policy, regulatory and incentive mechanisms

Comparative research about the role and potential impact of policies, conventions, laws, regulations, incentive mechanisms at global, regional, national or municipal levels, to develop equivalent mechanisms locally. Examples of these topics are as follows:

– Policy analysis and local/national proposals for legal and regulatory measures, including locally adapted incentive mechanisms.
– International agreements about environmental justice: Aarhus convention [b-Aarhus 1998], Escazú agreement [b-Escazú 2018].
– National "green new deal" for public policy to address climate change combined with achieving other social aims like employment and reducing economic inequality.

– Standards for non-financial/social/environmental reporting for the accountability of large private organizations.
– Tax incentives for good practices, tax related mechanisms such as sales tax e.g., value added tax (VAT) for reused and repaired goods.
– National e-waste policies adapted to local conditions, including aspects such as trading and exposure to hazardous e-waste, promotion of good practices for ICT recycling and standards for recycled materials.
– National circular economy policy adapted to local conditions; import and export regulations; compliance of international agreements; green public procurement; eco-design; requirements to provide information on chemical and material composition of products; phasing out hazardous substances from products; extended producer responsibility schemes; and other optional or mandatory product labelling (e.g., repairability, durability, recyclability standards).

Inventory of circular economy actors and adoption of voluntary quality procedures and labels.

Appendix I shows the example of KU Leuven in Belgium towards research on policy solutions for addressing the environmental and health problems caused by e-waste management in developing countries and countries with economies in transition.

8.4 Transfer knowledge and solutions to society

Engaging with the surrounding communities, regions and countries can contribute to increasing readiness (maturity) of the solutions for local applicability. IHL can:

– Provide reliable, trusted information to the public and diverse stakeholders.
– Propose practices for replication to other organizations.
– Create spin-off initiatives from research, education, service-learning.
– Develop policy recommendations and incentive mechanisms, according to local conditions and global cases.
– Develop certification requirements and impact monitoring procedures.
– Build and demonstrate experimental recycling facilities, in collaboration with internal and external actors, such as social and trade enterprises, such as in the case of [b-ITU-D 2018].
– Provision of open datasets for local, regional, national reference, statistics, aggregation and transparency.
– Be an inspiration for the surrounding city to be used as a blueprint for other organizations to follow.

8.5 Public awareness and advocacy for accountability

Public institutions from local to global scope have a responsibility in raising collective and individual awareness about a transition to a circular economy of EEE, ensuring it happens at the right pace, helping citizens and organizations determine their commitments and efforts to implement it, and informing them about the achievements resulting from collective action. Concrete proposals for principles and mechanisms to implement these principles with policies and regulations are given below:

Public education programmes can help citizens realize the environmental and social benefits of circular models, the unfeasibility of the take-make-waste linear model, and the rights and opportunities for citizens and circular business models.

Impact transparency and accountability by governments and regulatory agencies. Ensuring the right to know about the environmental impact and social responsibility involved in end-of-use devices. Examples include:

– Information about what buyers do with their devices and what manufacturers and recyclers do with the devices they collect for recycling (i.e., there is a need for integrated waste management systems). If recycled prematurely, manufacturers and recyclers must pay the social, environmental and economic costs (future opportunity cost) of having to manufacture new devices. If recycled inadequately (for example, due to insufficient investment) it results in the non-recovery of many materials that cost more to extract through mining than the value of the raw materials obtained (there is a need for open data for accountability, auditability of durability, circularity, audits on environmental impact, etc.)
– The production of open-data sets [b-eReuseData 2019] about real repairability and durability of devices will help local consumers to make informed decisions to buy more durable goods.

8.6 Engagement in the processes of EEE

Administration and management at IHL can be quite challenging. IHL campuses can be compared in requirements to towns, given the scale, diversity, and diverse services to be provided with the expected quality and auditability for the internal governance of the IHL and their accountability and auditability. Among them, the management of EEE and specifically ICT devices is key in the context of this Recommendation. The IHL management is required to organize the processes around the lifecycle of the EEE and specifically the ICT devices on campuses. The cycle starts with the procurement of ICT devices, as useful e-resources for given tasks, continues with the asset registration and maintenance of the devices acquired and used, and finally with decommissioning the results for external reuse and final recycling of e-waste that includes disposal or recovery of any useful resource as energy or secondary materials. These processes definitely involve the management of the technical staff with the duty of handling the ICT devices. It also involves research activities when the circular management of the ICT devices is connected to the research and educational activities, as well as service learning [b-Lopez 2015] involving students in activities working with their communities, such as the preparation for reuse or e-waste management workshops, as a user-centre, open-innovation ecosystem, integrating concurrent research and innovation processes within a public-private-people partnership. These user-centred activities that are multi-disciplinary in nature, can attract different departments and disciplines (e.g., material and industrial engineering, computer systems, software systems, economics, journalism, environmental sciences, chemistry, medicine, social work). Experiences such as [b-ITUDE 2018] in Argentina with support from ITU, [b-Lopez 2015], and in the Kingdom of Spain (Spain) given in Appendix IV, or Mexico in Appendix II are examples of user-centred activities.

8.6.1 Public procurement

Each IHL, or through purchasing consortiums, prepare large volumes of public procurement contracts of the ICT that can include clauses to ensure compliance with the environmental (e.g., eco-design, life cycle assessment (LCA), quality recycling) standards, labour, safety and quality standards in the supply chains of the ICT hardware goods they purchase [b-EW 2020].[1]

These clauses can include not only the due diligence of suppliers regarding the compliance of a set of requirements, but also requirements about take-back, further reuse, and responsibility on e-waste by certification and cost supplementing for good quality recycling that maximizes resource recovery and minimizes disposal and effects. A green procurement policy and the procedure is exemplified by [b-UCTG 2013] from the University of Cape Town.

[1] One best practice is the Electronics watch NGO, established in 2015, is an independent monitoring organization, bringing together public sector buyers and civil society organizations in electronics production regions, with experts in human rights and global supply chains. Electronics watch focuses on monitoring electronics supply chains from component through the final assembly and manufacturing of finished ICT equipment. Several European IHL and consortia are members. See: https://electronicswatch.org/en/contracting-for-change_2548241

A circular (lifecycle) perspective must consider a whole life cycle costing model, which should account for:

– Energy use during the life of the equipment.
– Packaging reduction targets or schemes, both connected to the concept of eco-design [ITU-T L.1023].
– Reuse, refurbish, recondition or re-allocation of end-of-life equipment to vulnerable students, NGOs and local communities.
– Waste reduction and carbon reduction measures.
– Methodology for disposal in an environmentally sensitive way, of any equipment that new purchases will displace as well as other obligations for new equipment placed in the market under the WEEE applicable regulations.
– External accreditations, such as [b-ISO 14000] or equivalent, for environmental management.

Purchasing consortiums are not-for-profit buying organizations but are owned by their members whose main aim is to secure the best possible value for themselves in the procurement of goods and services, without causing harm to others. Purchasing consortiums that group the number of devices required by all the public IHL or other public institutions in an area, can have a stronger capacity to convince suppliers to comply with the conditions set in calls for tenders, as well as improve the quality, cost efficiency and effectiveness of procurement processes and the verification of compliance of results.

Several examples:

– London universities purchasing consortium [b-LUPC];
– Consortium of university services in Catalonia [b-CSUC];
– Advanced procurement for universities and colleges in Scotland, with a case of procurement detailed in appendix III.

Either alone or as part of a purchasing consortium, IHL may have agreements with selected (certified) suppliers that allow purchases of individual devices or as part of lots of generic devices (purchased in large quantities in batches e.g., for the needs of an academic semester). Purchases follow a process, usually coordinated by digital tools, that includes and concludes the acquisition with the registration of the device in an inventory system of the organization. This is usually associated with a maintenance and an insurance contract. Devices can be moved to different functions once they become unsuitable for its primary purpose (internal reuse) and may include a service to collect and handle the devices at the end of use.

IHL can become models, and the contractual clauses can be published to become templates and have a trickle-down effect because they are trusted institutions. In this procurement process, researchers may be involved as a well-informed reference and as observers, allowing these researchers to perform an analysis and research about the implementation and impact of these programmes.

8.6.2 Inventory or asset register

There are standard procedures to tag devices with codes using ID tags to facilitate identification for tracking and handling of these assets during the usage cycle, maintenance and end-of-use phase before final disposal. This facilitates internal reuse in the owner's organization, such as use in a less demanding purpose, when a device is no longer fit for the initial purpose but is still considered a useful device for an alternative purpose, showing that there is still an interest in maintaining it as part of the inventory of the organization. This is usually influenced by the accounting criteria of depreciation or amortization, and also a technical criterion of usability and maintenance cost. An internal reuse policy combined with disposal for external reuse or otherwise known as recycling is exemplified by [b-UCTG 2015] from the University of Cape Town.

The lifecycle of the ICT devices can be followed across the inventory system, with staff and volunteers involved in the process that ensures these devices serve the academic purpose in IHL with sufficient quality of service. This further bridges the gap between all processes from purchase to the end-of-life disposal, related to traceability or circularity to ensure maintenance of devices.

Inventory systems imply that each asset registered in the inventory system can be tagged with a unique identifier. It is a common practice that these physical tags include a written identifier and an optical machine readable device, e.g., quick response (QR) code or an electromagnetic e.g., radio frequency identifier device (RFID), near field communication (NFC), element to facilitate reading.

Any maintenance, repair, upgrade, reuse and final decommissioning is usually associated with updates to the inventory system of an institution as a key e-resource, and the data it generates can be of interest to the IHL management and its technical staff, and it can also serve as a research topic in a living lab campus model.

8.6.3 Decommissioning

At the end of the EEE's useful life, EEE can either be collected by the supplier, sold or donated to non-profit entities, according to the organizational values, policy and procurement agreements. These practices risk breaking traceability that could ensure final proper recycling. Therefore, if the purpose and policy of IHL organizations are to ensure final recycling, certified traceability and impact assessment must be a requirement, and should be provided by the receiver of these EEE devices.

The choices and details for the treatment of resource recovery and final disposal determine the cost and effectiveness in terms of human and environmental impact. Therefore, choices, cost, transparency and accountability (traceability) are the key to determining the overall environmental impact of IHL and other organizations.

Several IHL, individually or through purchasing consortiums, have agreements for IT equipment recycling and e-waste disposal with external suppliers, which also implies the collection and logistics, such as storage and volume, sometimes as pallets or other types of volume (storage) handling, and associated traceability and accountability of these processes according to e-waste management regulations. These contracts may regulate the level of service, quality, costs and guarantees. Aspects such as the extended producer responsibility of manufacturers can play a role to cover the cost and compensate recycling, including treatment and the recovery of resources.

Some universities have internal recycling facilities [b-ITU-D 2018], where devices are triaged to either follow a repair and reuse path, or dismantled to extract reusable components and finally the remaining fraction going to e-waste processing, extracting any useful resources such as energy or secondary materials, and finally sending the remaining waste fraction for external processing, either through disposal in a landfill or for further processing at third party facilities, having positive or negative values (getting paid or having to pay for processing).

Appendix V exemplifies a policy from the University of Cape Town for internal reuse and disposal of devices for external reuse or final recycling.

8.6.4 Recycling

Recycling, and its process can reduce the impact on people and the environment from leakage of toxic materials and exposing workers and citizens in general to hazardous substances and preventing depletion of natural resources, particularly scarce materials. Highly sophisticated processing techniques can also extract additional reusable materials and reduce the disposed fraction. Different disposal processes have different costs and impacts [b-ITUDE 2018]. Processing ends when it becomes more expensive for the processor than the obtained value of the extracted resources. **Research and experimentation into more cost-effective separation and extraction practices can have positive impacts.** Economic incentives, recycling audits combined with direct investment to cover the cost of the added elaborate recycling, can supplement the value from extracted materials and result in more effective recycling.

Appendix II shows the example of the Autonomous University of Nayarit in Mexico in devising participatory projects for e-waste collection and management, from an emerging economy. The experimental e-waste processing plant in the National University of La Plata in Argentina, in collaboration with ITU [b-ITUDE 2018], is a reference work by an IHL with a post implementation assessment [b-ITU-D 2018].

9 A set of recommended actions for IHL

The involvement of IHL as stakeholders in national and local management is a recommended requirement. There must be spaces where the IHL can participate with governments to know about the needs, discussions, experiments and propose solutions that must be resolved at the local, national and global scope, in e-equipment, e-waste, circular economy, among others. In this way the actions undertaken by the IHL can serve to resolve local and national situations without remaining as isolated parties and seen as disconnected from national or local managements.

Delivering potential requirements for IHL to be supported with the required human, infrastructure and economic resources, supported by national, regional and international public and private funders; provides the required resources to support their implementation by IHL.

Based on the range of ITU-T Recommendations referenced in clause 2, the following table summarizes the set of recommendations, actions and the potential role of the IHL.

Recommendation	Action by IHL	Potential role of IHL
Awareness ITU-T L.1022	Development of locally relevant, public and reliable information and open datasets	Research: analytical framework, collection of quantitative and qualitative data
Definition of strategic goals ITU-T L.1015, ITU-T L.1020, ITU-T L.1030, ITU-T L.1031, ITU-T L.1470	Identification and adoption of goals and targets for sustainable ICT	Research: identification and selection of locally relevant issues for the HL institution and its area of influence (region, country)
Implementation of procedures and processes	Development and pilots of procedures, processes	Practice: design and implementation of mechanisms, teams in IHL dealing with circular processes
Procurement b-ITU-T L-Sup.20, ITU-T L.1010, ITU-T L.1020, ITU-T L.1021, ITU-T L.361	Adoption of responsible procurement of ICT devices Partnerships for procurement consortia	Analysis and implementation of public procurement criteria and clauses
Disposition, recycling ITU-T L.1032, ITU-T L.1100	Adoption of responsible disposition for reuse and recycling	Analysis and implementation of responsible disposition criteria and clauses as part of procurement contracts
Impact assessment ITU-T L.1023, ITU-T L.1015, ITU-T L.1400 ITU-T L.1410, ITU-T L.1420, ITU-T L.1430, ITU-T L.1440, ITU-T L.1450, ITU-T L.1460	assessment of social, economic and environmental impacts of EEE and WEEE in countries, regions	Research: assessment of social, economic and environmental impacts of EEE and WEEE in HL institutions in all circular processes
Training	Organization and delivery of specific training courses and learning activities	Training and learning: design and implementation of training and learning activities

Recommendation	Action by IHL	Potential role of IHL
Collective action, climate change adaptation ITU-T L.1500	Hackathons to prepare devices and collect e-waste	Organization of collective actions in IHL campuses by bringing expertise and interest to put knowledge into action in changes, to moderate the effects of climate change
Transfer ITU-T L.1024	Development, experimentation, piloting and transfer of knowledge, solutions, circular business models	Transfer: generation of spin-off businesses from internal IHL experiences
Policy contributions: ITU-T L.1021, ITU-T L.1032	Development of policy contributions related to policy pilots in IHL about processes and impacts on people and the planet	Research: experimentation and policies for practices in IHL Transfer: feasibility studies for policies

The resulting actions and outcomes elaborated by the IHL should facilitate the adoption by governments of domestic policies that facilitate a circular economy transition [b-OECD 2020] in line with the connect 2030 agenda [b-ITUC 2018].

Thinking and acting locally about the societal and environmental challenges can effectively contribute to compliance with global goals and agreements for a more sustainable planet.

10 Conclusion

IHLs are effective organizations to learn, adopt, research, experiment, manage, develop, pilot, adjust, propose and transfer to the local, regional and national citizens, public and private organizations at multiple levels, relevant instruments (such as limits, goals, indicators, practices, monitoring, incentives, policies) to manage EEE, adapted to local conditions. Transfer of knowledge to community practices and policy contributions can bring about transformative innovations originating from campuses, and reaching the surrounding communities, regions and countries. The results can be effective and efficient circular processes adapted to local conditions that minimize social, economic and environmental impacts of EEE and WEEE.

Appendix I

The role of institutions of higher learning in educating different categories and research related to policies

(This appendix does not form an integral part of this Recommendation.)

This contribution offers an example of higher learning institutes playing an active role beyond the borders of the campus. The university plays its role in a multi stakeholder model to increase capacity building and awareness among different categories of learners in the community through massive open online courses (MOOCs), research and curricula on hazardous e-waste management. Take the example of KU Leuven which developed the "E-waste challenge MOOC in cooperation with partners (see below). It shows how institutions of higher learning can play a key role in bridging the gap between standards and practices.

Making standards is one thing, turning them into action requires further capacity building

According to Mr Bas de Leeuw, managing director of the World Resources Forum (WRF), the relaunch of the MOOC on electronic and electrical waste has come at the right time: "*Circular Economy is attracting worldwide attention, in particular stimulated by the programs of the European Commission and others. We need to make sure that this not only makes sense for the environment but also for the economy, and for wellbeing and human development in developing countries. At the WRF we have hands-on experience in this field through our Sustainable Recycling Industries (SRI) program, and we are very pleased to be able to share our knowledge and skills to the wider community. Making standards – which is a core priority in our portfolio – is one thing, turning them into action requires further capacity building and supporting all stakeholders in the value chains*."[2]

MOOC launched by the UN and its partners to galvanize action for managing hazardous e-waste

It is estimated that, by 2050, there will be about 120 million metric tonnes of e-waste produced per year, far-outstripping current capacities to properly manage it in an environmentally and socially appropriate manner. The secretariat of the Basel, Rotterdam, and Stockholm conventions (BRS), together with its partners the European Institute of Innovation and Technology's climate knowledge and innovation community (EIT Climate-KIC), the European Institute of Innovation and Technology's raw materials knowledge and innovation community academy (EIT RawMaterials), the International Telecommunication Union, **KU Leuven** and the World Resources Forum, launched an updated massive open online course, or MOOC on electronic and electrical waste – or e-waste – together with contributions from the World Health Organization (WHO).

Awareness raising through MOOCs

This MOOC introduces learners to the challenge of e-waste and especially to its environmentally sound recycling. The course will guide learners from different categories through the problem, to opportunities, and possible actions at local, national and regional levels, and will introduce learners to policy tools, standards and best practices for collection, recycling, and the final disposal of e-waste.

The MOOC enables stakeholders across the world – in developing and developed countries alike – to access valuable e-waste resources, insights, best practices, standards and tools, and translate these into practical actions to protect people's health and the environment.

[2] https://www.wrforum.org/other-publications/mooc-on-electronic-and-electrical-waste/

The MOOC is based on multiple partners reflecting the complex nature of the topic and the need for synergies among different stakeholders:

WHO contributes from the health perspective: seeking to communicate the evidence, information and the tools available to address this emerging e-waste health hazard, to raise awareness, and advocate for multisectoral policies that promote and protect children's health and their rights.

The University of KU Leuven: plays an important role in the MOOC by showing the huge opportunities of a circular economy for electronics in saving resources, lowering the environmental footprint and recovering value, and the close link it has with climate change mitigation. KU **Leuven** is Europe's most innovative university (according to the news agency Reuters) and ranks 48th in the Times Higher Education (THE) world university rankings. As Belgium's largest university, KU Leuven welcomes close to 60 000 students from over 140 countries. Its 7 000 researchers are active across a comprehensive range of disciplines. KU Leuven is a founding member of the League of European Research Universities (LERU) and has a strong European and international orientation.

The MOOC is aimed at students and researchers, policy makers in the environment and telecommunication sector, practitioners, entrepreneurs, e-waste recyclers and government officials and invites participants to become part of the solution to this growing problem. Relevant for developed and developing countries alike, the eight-week programme covers all aspects of e-waste with a view to turn the threat of this global explosion of e-waste into an opportunity. The course is organized into five mini-courses which can be taken one after the other or independently. The E-waste challenge MOOC is presented in five stand-alone and comprehensive online mini-courses, it is self-paced and introduces challenges and possible solutions for the environmentally sound management (ESM) of e-waste. Participants can follow either a long track of all the five mini-courses or a short track by selecting only some mini-courses.

The course will help participants to understand why and how to manage e-waste in an environmentally sound manner and how action on e-waste can be taken within one's life, business, or organization, with the aim to:

– Show how sound management of e-waste can help reduce GHG emissions, mitigate climate change and prevent hazards to health and the environment in accordance with the Basel, Rotterdam, and Stockholm conventions;
– Share best practices, technological innovations, and sustainable e-waste recovery and inclusive recycling business models;
– Present innovative research on technological solutions to reduce hazard by design;
– Explore how the value in e-waste can be extracted in a way that supports the local economy and protects people's health and the environment, evaluating the socio-economic impacts of this change into more sustainable business models;
– Explore incentives and opportunities for e-waste recycling;
– Advocate for the environmentally sound management (ESM) of e-waste.

The course includes five mini-courses of about six-eight (6-8) hours each, including time to complete the assignment tasks. (Modules do not equate to weeks – this can be spread across a longer period).

– Mini-courses 1 and 2: Introduction to e-waste – Issues, impacts and solutions
– Mini-course 3: E-waste and children's health
– Mini-course 4: Reducing e-waste by design, standards, business and policy
– Mini-course 5: Environmentally sound management and inclusive e-waste recycling

Learners who complete the first and second mini-courses, and each of the other mini-courses will receive a certificate. Learners who complete all the five mini-courses will receive a certificate from the United Nations Environment Programme (UNEP), Secretariat of the Basel, Rotterdam and Stockholm conventions (BRS) and a European Institute of Innovation and Technology (EIT) Climate

KIC certificate after course completion, including the contributing organizations. The MOOC will be accompanied by webinars live events, chat room discussions forums, and interactive features, as well as an available e-learning course.[3] The E-waste challenge MOOC that opened in February 2020 has attracted more than 6 000 students in the minicourses and the live webinar lectures during the year 2020. The E-waste challenge MOOC is updated and re-launched periodically by KU Leuven and its partners.

In addition, KU Leuven works on (WEEE) from the policy perspective: A major challenge for the research community is to find effective (policy) solutions for addressing the environmental and health problems caused by e-waste management in low- and mid-income countries while, at the same time, enhancing the recovery of precious metals to reuse these resources. KU Leuven attempts to analyse why emerging economies adopt e-waste policies that seem inadequate and ineffective in their local contexts and also identify alternative approaches. The first step involves developing a novel analytical framework to analyse the effectiveness of e-waste policies in emerging economies and, as a second step, it seeks to explain the degree of effectiveness of e-waste policies in India and South Africa (RSA).

The research aims to make conceptual, empirical and policy-relevant contributions: Researchers strive to contribute to the academic literature by developing a novel analytical framework that helps evaluate e-waste policies in non-western countries. Current literature on e-waste is largely based on assumptions derived from western policies, politics and societies. By analysing the cases of India and South Africa, the research will focus on two countries whose e-waste policy has barely been analysed. The findings of the project will provide insights that both the EU and non-European policymakers can use in their decision-making. The EU has a keen interest in supporting non-EU countries tackle their e-waste challenges through effective policies, especially since parts of the e-waste that causes problems in those countries originates from the EU and are a direct result of European consumption.[4]

Other stakeholders

The Basel, Rotterdam and Stockholm Conventions Secretariat. The Basel convention on the control of transboundary movements of hazardous wastes and their disposal is the most comprehensive international environmental agreement on hazardous and other wastes and is almost universal, with 188 parties[5]. With an overarching objective of protecting human health and the environment against the adverse effects of hazardous wastes, its scope covers a wide range of wastes defined as hazardous based on their origin and/or composition and characteristics, as well as waste defined as "other wastes", namely household waste, incinerator ash and plastic wastes.

EIT Climate-KIC is Europe's largest public-private partnership addressing climate change through innovation to build a net zero carbon economy. With over 380 formal partners from across 26 countries, its mission is to catalyse systemic change for climate action through innovation in areas of human activity that have a critical impact on greenhouse gas emissions – cities, lands, materials and finance – and to create climate-resilient communities. Education underpins these themes to accelerate learning and to inspire and empower the next generation of climate leaders.

EIT RawMaterials Academy, initiated and funded by the EIT (European Institute of Innovation and Technology), a body of the European Union, is the academy of the largest consortium in the raw materials sector worldwide. Its vision is to develop raw materials into a major strength for Europe. Its mission is to enable sustainable competitiveness of European minerals, metals and materials sector along the value chain by driving innovation, education and entrepreneurship. EIT RawMaterials

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[3] http://www.basel.int/Implementation/TechnicalAssistance/MOOC/tabid/4966/Default.aspx

[4] https://soc.kuleuven.be/lines/sustainable-futures-research-group/research/e-waste

[5] As of 30 April 2021.

unites more than 120 core and associate partners and 180+ project partners from leading industries, universities and research institutions from more than 20 EU countries.

The International Telecommunication Union (ITU) is the United Nations specialized agency for information and communication technologies (ICTs), driving innovation in ICTs with a global membership including 193 Member States and over 900 companies, universities, and international and regional organizations.

The World Resources Forum (WRF) is best-known for its annual flagship events, providing the global platform for multi-stakeholder dialogue on resource governance and resource efficiency. The WRF Secretariat also leads or contributes to large projects in these fields, including the Swiss-funded sustainable recycling industry (SRI) programme, a range of EC Horizon 2020 coordination and research projects – FORAM, CEWASTE, RE-SOURCING and CICERONE – and several projects with the United Nations, development agencies and industries. Together with UNEP the WRF has published a MOOC on decoupling (Resource Revolution Trainer), and together with the BRS Convention Secretariat and its partners has also published a massive open online course (MOOC) on electronic and electrical waste www.wrforum.org.

Appendix II

The role of institutions of higher learning in devising participatory projects for e-waste collection and management and examples from emerging economies

(This appendix does not form an integral part of this Recommendation)

Universities play an important role in devising new mechanisms for e-waste management and disseminating them to the community. This contribution presents the Recyclotron project of the Autonomous University of Nayarit in Mexico [b-Saldaña-Durán 2021].

The Recyclotron project of the Autonomous University of Nayarit in Mexico

Electronic waste is one of the main environmental problems caused by the dynamics of consumption. E-waste disposal concerns all the stakeholders, from policymakers to the end users. Hence, an assessment of the overall sustainability of e-waste, considering the three pillars: environmental, economic, and social, is an important task. Higher education institutions are called to adopt sustainable development strategies to give a positive impact on the community. This appendix presents the assessment of the programme for selective collection of electronic waste, called Recyclotron, implemented at the Universidad Autónoma de Nayarit (Autonomous University of Nayarit), in Mexico. The objective of such a programme is to promote a culture towards sustainability in e-waste management at the university campus, as well as to be a reference for social and environmental responsibility for the community.

It is necessary to improve e-waste management mechanisms and define them as products, components, materials, and substances of high environmental risk because of their content of dangerous toxic elements [b-Julander 2014]. More studies on management for final disposal of e-waste, in order to have better data to track these trends, are needed.

The university plays an important role in developing policies as one of the main stakeholders

The complexity of e-waste management suggests that the development of public policies must focus on awareness and social participation. Proposals should be established from interest groups, such as institutions of environmental regulation, institutions of higher education, government, and society. A committed relationship between different social actors and sectors is required to promote collaboration towards the design of laws, programmes, and strategies to prevent and reduce negative impacts on the environment and human health damage related to e-waste management [b-Cao 2016]. Institutions of higher learning are called to adopt sustainable development strategies and yield a positive impact on social, economic, and environmental activities of the community since they are not exempt from the problem of e-waste management.

Universities have the privilege of having different disciplines co-existing and thus can play a role in reshaping the understanding of managing e-waste across different categories of students

Moreover, environmental management and specifically e-waste management is a complex and multidisciplinary activity that requires the participation of all the stakeholders, from policymakers to the end users, as well as professionals experienced in this matter [b-Debnath 2018]. Since the early 1990s, a large number of international studies on the responsibility of universities to adopt a culture of sustainability through teaching, researching, managing, and engaging with society have been published [b-Ramos 2015]. Many institutions of higher learning (IHL) are already operating innovative programmes and projects in environmental management [b-Disterheft 2013]. IHL acknowledges the importance of these topics in developing positive attitudes that encourage a change of culture, as well as the awareness for collective commitment and the search for viable alternatives that bring together all actors towards a mutual commitment to environmental conservation [b-Adeniran 2017].

Current trends require new forms of education in building sustainability, the agenda 2030 of the United Nations Development Programme (UNDP) states that the Education for Sustainable Development (ESD) programme is not only achieved by technological solutions, political measures and economic resources – we must also change our way of thinking and acting. To achieve this goal, education for sustainable development is needed at all levels and in all social contexts. Therefore, institutions of higher learning are seen as trainers for new professionals and are called to work together and create a better world to achieve sustainable human development. Nowadays, IHL are also called to create a better and self-sustaining world.

The university engages the student body

The proposal of a waste management plan for education institutions in developing countries demonstrates that the implementation of a model based on the continuous improvement cycle has a high probability of success, even in scenarios where financial resources are scarce, in addition to the socioenvironmental benefits due to the multiplier agent factor that education institutions play in disseminating information and consolidating the idea of socio-environmental responsibility [b-Fagnani 2017].

Comprehensive management of hazardous waste programmes in some Mexican universities have been successfully implemented; however, results on e-waste management are not found in recent literature. Universidad Autónoma de Nuevo León was the first education organization in Mexico to receive an environmental quality certificate after implementing a hazardous waste programme [b-Ramírez Lara 2017].

As a response to the problem of inadequate management of e-waste, few more Mexican universities have organized activities focused on selective collection of waste: Universidad Autónoma de Baja California [b-Armijo de Vega 2003], Universidad Autónoma Metropolitana [b-Espinosa 2008], and Universidad Nacional Autónoma de México, among others. Universidad Autónoma de Nayarit started the programme of selective e-waste separation, called "Recyclotron" as a proposal for on-campus solid waste management as an initiative from students and professors.

It means an opportunity for non-formal education towards sustainability of e-waste management university on campus. ESD requires participative approaches to involve students in the on-campus promotion within the university community for creating a recycling culture, environmental awareness, and public health problems caused by excessive waste generation and its inadequate final disposal.

Recyclotron has the goal to promote a programme of selective waste collection as a strategy towards sustainability in waste management at the university campus. A methodology based on recycling logistical process includes five stages: (1) collection; (2) classification; (3) quantification; (4) recoverable fractions; and (5) commercialization.

The programme of e-waste recycling: Recyclotron is carried out mainly through the active participation of students from diverse engineering programmes, engaged in developing the process of e-waste management. Firstly, students are in advance trained and taught to advertise environmental and human health hazards involving e-waste handling. Tasks are then assigned to each team of students involved in each stage of the process. As an incentive for them, the five stages of the process form part of a workshop with value, authorized by the university board department and counts as an elective course.

Stages of the Recyclotron process

1. Collection: During the process of Recyclotron, the students are organized into teams and then receive, pick up, and weigh the collected e-waste.

2. Classification: Collected devices are categorized in six different types according to the Mexican Official Standard NOM-161-SEMARNAT-2011: (1) Desktop and accessories, (2) Portable computers and accessories, (3) Monitors and television (TV) with cathode ray tubes (CRT), (4) Portable audio and video players, (5) Printers and multifunction printers, and (6) Others.

3. Quantification categorizes devices by type, these devices are disassembled by a manual mechanical process, following the safety rules previously established in the training. Separation of materials in the e-waste chain requires the hard work of performing manual disassembly. Dismantling is done by using screwdrivers, hammers and chisels, to obtain materials and components. Safety rules require the use of suitable gloves, masks, shoes, and caps in this stage. Separated materials are classified into different groups such as scrap, plastic, iron, keyboards, cables, hard disks, motherboards, copper, aluminium; then the materials are weighed for their quantification.

4. Recoverable fractions: Once the materials and recovered fractions are **classified** and quantified, they are designated for different recycling purposes, as well as reuse. At this stage, engineering students can stock up for themselves, electromechanical and electronic devices such as transformers, voltage sources, transducers, capacitors, resistors, diodes, displays, sensors, small motors, among others. Subsequently, such devices are reused for practices and projects in the laboratory, as well as in the development of new devices.

   This stage of the process is very important since it promotes suitable e-waste management, recycling and adequate disposal of e-waste. It also represents an economic benefit for students as well as an environmental benefit to ecosystems by avoiding tons of e-waste ending up at the municipal dump.

5. Commercialization: Materials such as plastic or metals, available for purchase by local recycling companies, are sold considering market value prices. The performed sequence presented here had been carried out every two years, for four times.

Recyclotron is allowed to institutionalize electronic waste management at the university campus and will also help to design public policies on the responsibility of manufacturers and consumers in the handling and final disposal of e-waste. Efforts from the academy in this work focuses **on participative methodologies** to create synergies that lead local decision-makers to adopt models of waste management, as well as provide valuable information about the hazardous nature of e-waste and their impacts on water and soil pollution caused by their inadequate management [b-Wang 2017].

Regarding student participation, it is important to know that the university campus has a population of 12 960 students, of which 5.5 % belonged to the engineering group. During the first instance, the Recyclotron team was composed of 20 student leaders who represented 2.8 % of the students' population of the engineering group. During the fourth instance of Recyclotron, the student's participation increased from 20 to 130, reaching 20 % of the participation of engineering students.

This work offers a useful instrument for achieving suitable e-waste management as a strategy towards sustainability in institutions of higher learning (IHL). The relationship between students participating in Recyclotron and the amount of collected e-waste has increased each instance of the Recyclotron project, hence more social responsibility was observed, which was similar to the results presented by [b-Lederer 2015], who observed quite a number of concerns that local communities have regarding municipal solid waste management, but also a high willingness of community members to get involved in activities to improve such situations. Government, society, academies, waste collection and recycling companies working together was an organization strategy observed by [b-Sedlacek 2013], as being the key to success in this type of work.

The knowledge acquired through this experience allowed the students to promote environmental awareness. **It is expected that the university provides tools for the understanding of**

environmental issues under a more holistic view, instead of relying on traditional pragmatism and reductionist approaches [b-Fagnani 2017].

Conclusions

According to future projections, it is estimated that for the next Recyclotron, more than 25 tons will be collected. The approach of this case study can be adopted by other institutions of higher learning in developing countries to reduce the negative impacts that the mismanagement of e-waste causes on the environment. An important aspect that emerged from the implementation of the Recyclotron is its proposal as a teaching strategy in higher education, thanks to the collective cooperation of the students and the cognitive skills that were developed when participating in the project. The experience also provided the students with academic skills and thus, analysing these cognitive and academic skills for quantification must be considered. This will motivate people to continue directing research efforts on this subject in the future.

Appendix III

The role of institutions of higher learning in socially responsible public procurement of audio-visual equipment

(This appendix does not form an integral part of this Recommendation.)

Extracted from [b-APUC 2020]:

Advanced procurement for universities and colleges (APUC) is the procurement centre of expertise for Scotland's universities and colleges. APUC has broad and deep experience in integrating criteria relating to both environmental as well as social aspects into its procurement. Its sustainable procurement approach is ingrained in all the steps of its procurement process – from strategic development, to tendering and contract management, with its entire staff experienced in questions relating to sustainability. The core of the APUC's work is to support universities and colleges across Scotland to implement sustainable public procurement.

Sustainability and social responsibility are key drivers within the APUC. It is a founding member and an Electronics watch [6] affiliate. Ethical trading, environmental impact reduction, equality and diversity considerations are some examples of the typical concerns of the APUC and its staff members while serving their wider community.

As collaborative and blended learning approaches become more common among universities and colleges, the demand for audio-visual equipment has increased. As such, in 2018, in collaboration with universities and colleges across Scotland, the APUC decided to integrate social and environmental requirements into its procurement of audio-visual and video conferencing equipment.

Following the disruption to education caused by COVID-19 (coronavirus disease) and the move to more technology-enabled learning, the need for socially responsible and environmentally efficient audio-visual equipment has only increased.

The award criteria of the APUC is used to evaluate how bidders will encourage sustainability in the provision of goods and services for these types of contracts. Contract performance clauses are also used to ensure compliance with APUC's supply chain code of conduct and encourage social value creation. For one of the lots, APUC used a whole life cycle costing model, which also accounted for energy use during the life of the audio-visual equipment.

Procurement approach

APUC set up three market engagement meetings, held over three days (two in Glasgow and one in Edinburgh). Suppliers from the previous framework agreement as well as companies that had been observed through an expenditure analysis were invited. A stakeholder group consisting of audio-visual experts and procurement managers belonging to some of the institutions also attended the meeting. To enable a focused and productive discussion, potential bidders were provided with a presentation subject, which included a section on sustainability and socially responsible procurement.

Social criteria used

Subject matter of the contract

The supply, design and installation of energy efficient audio-visual equipment, including video conferencing equipment.

Bids were evaluated based on the most economically advantageous tender (MEAT) approach, for both technical and commercial merits.

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6 https://electronicswatch.org/

– Lot 1: Technical 30 % (sustainable procurement 5 %) and commercial 70 %.

– Lot 2: Technical 70 % (sustainable procurement 5 %) and commercial 30 %.

Lot 1 – Supply of equipment and consumables: Sustainability criteria

Tenders were asked to identify any environmental issues their organization had encountered in relation to the sourcing and provision of the products listed in Lot 1, demonstrating how they addressed these issues, and will ensure compliance with all the statutory environmental obligations and effectively manage its environmental impacts during the delivery of the framework agreement which includes:

– Details of the organization's approach to achieving supply chain transparency i.e., understanding where products are manufactured and the working conditions within the sites. A supply chain mapping template was provided as an appendix;

– The methodology used to encourage reuse of equipment within the supply chain which may also be available to the institutions during the framework agreement;

– Any recyclable/reusable packaging targets set by the organization;

– The organization's approach to environmental management, including accreditations held and adhered to in the delivery;

– Staff awareness and training to be delivered/applied.

Lot 2 - Supply, design, installation and maintenance: Sustainability criteria

By having a detailed approach to the sustainable provision of products and services. The response must provide a detailed account of how the tender's organization addresses the following key areas:

– Managing social and ethical risk in the supply chain;

– Equipment or packaging reduction targets or schemes;

– Reuse, refurbishment, recondition or re-allocation of end-of-life equipment to local communities;

– Waste reduction and carbon reduction measures;

– Methodology for disposal in an environmentally sound manner, of any equipment that new purchases will displace as well as other obligations for new equipment placed in the market under the WEEE directive;

– Accreditation gains such as ISO 14001 (or equivalent);

– Community benefits and opportunities for new entrants (Please attach matrix).

The answer is limited to four pages of A4 size at font Arial size 11 plus community benefits matrix.

Lot 3 – Supply, design, installation and maintenance: Whole lifecycle cost criteria

Unlike Lot 1, which focussed on the supply of individual products, Lot 2, suppliers were asked to design solutions, and APUC wanted to challenge suppliers to provide designs that were sustainable i.e., energy efficient and durable equipment, with spare parts and future-proof design. Budget-wise, the majority of the spending was to be focussed on Lot 2.

Tenders were required to complete a "pricing schedule" (included as an annex to the call for tender) which would calculate the whole lifecycle cost of an audio-visual equipment.

To calculate the whole life cost, the following assumptions were made:

– The lifecycle of the equipment shall be five years;

– The cost per kWh is provided and shall be used to multiply all responses for the entire lifetime

– The equipment will be in use for ten hours, for five days each week and will be then switched to low power for 14 hours during the weekends and holiday periods;

– For the purpose of evaluation, it is assumed that there are 46 working weeks in a year, which will be calculated as 365 days;

– To calculate power consumption, the formula is [b-number of hours' use] x [b-number of days' use] × ([b-capacity of appliance expressed in watt] / 1 000) = number of kWh;

– The equipment shall include a five-year warranty and the institution would not require to purchase additional consumables during this five-year lifecycle. Tenders should also include itemized pricing for consumables required for the five-year lifecycle under the relevant equipment.

Pricing was compared using the formula: **[b-Lowest bid / Actual bid] * Marks available.**

Contract performance clauses

In the call for tenders, APUC stipulates that the contractor is encouraged to act at all times in an ethical, environmentally sustainable and socially responsible manner in the conduct of their business, as well as striving to improve quality standards and overall value for money. APUC is also seeking contractors who are willing to demonstrate a commitment to these values. This includes:

– compliance with APUC's supply chain code of conduct, which includes suppliers' commitment to not using forced, involuntary or underage labour;

– non-discriminatory behaviour and compliancy with living wage or minimum wage requirements;

– promotion of equality and diversity through the life of this framework agreement, including community benefits or social value where they are identifiable throughout the term of the framework agreement (including providing training opportunities to staff and students, apprenticeships and investment in the local community), where APUC will help the contractor identify;

– compliance with the Modern Slavery Act.

Contractors must have policies or plans to put a policy in place for the following:

– Sustainability considerations – socio/economic and environmental;

– Community benefits, social and equality targets/requirements;

– Considerations such as fair and ethical trading;

– Equality and diversity requirements.

The contract performance will be monitored at supplier review meetings, taking into account key performance indicators (KPIs). Contract review meetings will take place every six months. The focus so far has been on the reuse of equipment. Suppliers are also asked to complete the APUC's "Sustain" supply chain database, which is currently in its pilot phase. This database is designed to improve the knowledge and awareness of supply chains and practices within them.

Lessons learned

APUC used an award criteria to score supply chain mapping to improve supply chain transparency. The approach resulted in a variety of responses, with some suppliers providing details on their supply chains while others did not. Moving the requirement for supply chain transparency into contract management by defining a contract condition for contractors to provide supply chain transparency information within 30 days, will enable both sides to better manage the process. This will lower the workload during bid evaluation while at the same time making supply chain transparency a mandatory part of the contract.

Local audio-visual equipment resellers and installers only constitute a small group of suppliers. While these suppliers do not have much influence in the global supply chain, their awareness of the APUC requirements for supply chain transparency has increased, and has deepen their knowledge of the supply chain, whereby more points can be scored. This in turn encourages more attention to transparency at the next tier of the supply chain.

Appendix IV

The role of institutions of higher learning in devising participatory projects for preparation for reuse

(This appendix does not form an integral part of this Recommendation.)

eReuse.org

The Reutilitza (reuse) experience taking place since 1995 at the Polytechnic University of Catalonia in Barcelona (Spain) organized by the Centre of cooperation for development[7] involves professors and students in several subjects to prepare computers disposed of by the university for further use by social organizations. eReuse is a spin-off initiative that has scaled up beyond the university, supporting several social enterprises that collect and refurbish computers and mobiles, donated by the public and private organizations when no longer used. These devices are delivered to vulnerable citizens, supported by sponsors that cover the preparation cost and assist users in their use for social inclusion.

IV.1 Project / Programme overview

Disposed digital devices (computers, tablets, mobiles) are a resource for local social inclusion and participation. The vision states that public and private organizations act for the common good for a better, more inclusive and environmentally friendly internet, by donating their disposed devices to social enterprises that repair and refurbish them, then distributed to families that require devices to participate in education and socio-economic activities over the internet within their communities. This second-hand market creates social inclusion jobs, creating plenty of devices at the minimal cost of refurbishment, and feeds a circular economy that improves local socio-economic and environmental conditions.

IV.2 Problem statement / background

The challenge is the collection and refurbishment for the reuse of computers and mobiles for maximal lifespan ensuring final recycling. Digital devices that end a first usage phase from individuals and public or private organizations, can have a second life instead of being dumped or shredded. Refurbishers and repairers, either individually or usually as part of a social enterprise, can prepare these devices for new use (reuse) and offer them to users at the cost of the refurbishment process. This creates an inclusive offer for low-cost but useful devices.

For offering a refurbished low-cost device, there is a need to bootstrap collaborative local circular economy ecosystems across all stakeholders in the ICT reuse and recycling. eReuse has developed forums to coordinate different stakeholders in localities that can exchange complementary resources, skills, to balance supply and demand and share costs and help each other: device donors, refurbishers, citizen support organizations, recyclers to work together as part of a common-pool resource system of second-hand digital devices for extended use.[8] These different forums are called "local circuits".

The beneficiaries of the activities are citizens interested in second hand computers, citizens in municipal social support programmes, schools, public facilities and families supported by neighbourhood social support organizations.

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7 UPC Centre of cooperation for development https://www.upc.edu/ccd/en

8 Franquesa, D., Baig, R., Navarro, L. (2017). *Sustainability and participation in the digital commons*. ACM Interactions. https://interactions.acm.org/archive/view/may-june-2017/sustainability-and-participation-in-the-digital-commons

To be circular, devices are required to substitute the demand for newly manufactured devices along with ways to trace, certify and measure circularity (chain of custody) of products, members and its platforms. This way ensuring the best way of measuring social, economic, and environmental impacts.

This coordination and measurement require coordinated development of open-source resources for reusing electronics. This is the case for software tools[9] [10] to quickly and easily extract details, diagnostics and automation of inventory, triage and preparation of second-hand devices, generation of QR codes to stick on devices for traceability, as well as data formats and tools to collect and store data about the lifespan of each device, and compute impacts and reports.

IV.3 Implementation and current status

The eReuse initiative started in 2013, had an important milestone in 2015 with the launch of a computer donation campaign. eReuse now has more than 10 000 computers processed with the eReuse software tools. There are about 15 active social organizations, and several local "eReuse circuits" in Barcelona and Madrid.

In a typical circuit, a donor organization (public or private organization) donates decommissioned devices, that are collected by a social enterprise that brings these computers in pallets to a refurbishment facility operated by a social enterprise or a reuse centre. At the refurbishment facility the devices are put in a rack and are inspected, data is wiped, tested and reinstalled with (usually) a Linux distribution, in parallel with eReuse software tools. The devices that do not pass the test are put in a cage for recycling and recorded in the system and prepared for recycling. The devices that pass the test are cleaned, checked in more detail and sometimes upgraded (battery, random access memory (RAM), storage), labelled and stored for sale or donation (cost sponsored by a third party, although it is recommended that the final beneficiary contributes something as a commitment). Individuals but, usually social support or public organizations acquire these devices which are brought to end users with the commitment to return these devices to the intermediary organization after usage, for another refurbishment or final recycling. The eReuse software records all these transfers and can generate a complete provenance log for each device and its lifespan, without revealing any personal details about the users.

Agreements have been developed with public and private device donors, social organizations working with end-users, social enterprises in social inclusion programmes working with refurbishment and recycling. These agreements allow for data collection about the devices (chain of custody), data aggregation and analysis of social (usefulness of computing hours enabled) and environmental impact (CO_2e savings).

eReuse delivers training of actors about different aspects of device refurbishment as well as dissemination activities to raise awareness about environmental issues in ICT. Overall, this generates datasets about impacts and datasets and about the durability of the processed devices.[11] All the combined results in the key activities and the actors, improve the longevity of the devices with the opportunity of new reusage cycles for the benefit of helping more people with devices and mitigating the impact of ICT on the planet.

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[9] https://www.ereuse.org/software/ https://github.com/eReuse

[10] Franquesa, D., et al. (2015) *Breaking barriers on reuse of digital devices ensuring final recycling*. In EnviroInfo and ICT for Sustainability 2015. Atlantis Press (Best paper award). https://www.atlantis-press.com/proceedings/ict4s-env-15/25836176

[11] Franquesa, D., Navarro, L., (2020). *eReuse datasets, 2013-10-08 to 2019-06-03 with 8458 observations of desktop and laptop computers with up to 192 features each*. https://dsg.ac.upc.edu/ereuse-dataset

IV.4 Products, services and solutions delivered

Nearly 10 000 computers were traced in the dataset: 1 203 devices as shared property have been donated by 47 different donors and received by approximately 100 entities such as schools, public facilities, NGOs, and final beneficiaries.

IV.5 Sustainability, impact, outcome and output

Refurbished devices are prepared by workers of social enterprises or reuse centres, and sometimes by individual volunteers or students studying service learning. Devices have a (processing) cost that is paid by sponsors or receivers to refurbishers (as processing cost, since devices come from donations), in the range of EUR 20-120 each in Barcelona.

The main overall impact and outcomes are:

– Reduction of the environmental impact of ICT, with CO2 equivalent impact estimates.

– Universalization of access to computer devices, from the opportunity of using these low-cost second-hand computers to measuring the provided additional computing hours.

– Creation of jobs in computer refurbishment, which is linked to device collection and refurbishment.

– Reduction of ICT e-waste and environmental impact of ICT, with more durable devices through reuse.

– Development of software tools for more efficient (time, quality) processing of ICT devices which implies less refurbishment time per device, which results in lower processing cost and higher efficiency and salary for refurbishers.

– Collection of reliable open data to promote circularity (chain of custody), promote good behaviours, quantify and certify impacts. For instance, durability statistics on different models and brands can assist with purchase decisions and creating requests for more durable designs.

IV.6 Limitations and learning

The level of funding is a limiting factor in expanding the process to other regions. It implies initial training, development and certification of good practices, coordination of the tasks and management of a stable device demand and supply, development and maintenance of software tools and services.

A servitized business model has been developed where users pay for computing as a service, for instance, the number of operational computers in a school classroom, and actors of the circuit ensure a performance level and perform maintenance, upgrades and replaces to ensure the service contract for a given amount in exchange of a monthly or a yearly fee. This ensures they have the computing they need, but ownership remains in the circuit, making certain that the device performs well until it is maxed out and is finally recycled with some parts being reused. These recyclers are specialized in e-waste and can either be public, commercial or social enterprises dedicated to this process. The recyclers can participate in the eReuse data by recording the devices they receive by scanning any QR codes in the devices received.

Circuits work as long as there are minimum stakeholders (donors, refurbishers and users) with a minimally stable demand and supply to ensure efficient processing (ideally at an industrial scale). The process must be economically, socially and environmentally sustainable to persist and satisfy all parts of the key roles. For example, maintainers and support for final users are needed to overcome the barriers related to the behaviour of the final users and to ensure longevity and substitutability of the primary materials.

IV.7 Conclusion

eReuse has built a model of reuse circuits that works in different cities and regions in a country like Spain. The model appears to be effective in being economically, socially and environmentally sustainable. The coordination across complementary stakeholders helps to ensure the complete set of capabilities and skills to bootstrap a local circular economy of digital devices. The software tools allow the improvement of efficiency (processing time) and quality of the refurbishment. Collected data allows the calculation of impacts and reports to be sent to donors and the general public. Open datasets are useful to activists and governments to promote manufacturers and device owners to act responsibly for the challenge of developing a circular economy of digital devices that make ICT part of the solution to sustainable development (less inequality, less environmental impact) and not part of the problem (from the environmental impact of premature recycling devices after the first use and lack of impact assessment).

Appendix V

The role of institutions of higher learning in internal reuse and disposal policies

(This appendix does not form an integral part of this Recommendation.)

Based on publicly accessible policies from the University of Cape Town [b-UCTG 2015] and an interview with an IT person from one of the university's department, the university's policy consists of the following steps as summarized below:

– The university places a specific number of years for the lifecycle for desktop and laptop computers. Liquid crystal display (LCD) monitors are not subject to the equipment lifecycle and may be replaced at the time of failure.

– The university equipment supplier provides a four-year maintenance on computer equipment and the university provides another one year of warranty to extend and support a longer lifecycle.

– Old redundant equipments, that are usable, are advertised for repurposing. Other departments can also apply to transfer and take over the equipment at no cost.

– If the equipment is not taken up for re-use, then the central IT department advertises these on the internal university marketplace for sale to staff and students.

– Equipment can be donated if there is sufficient motivation, for example, a social response initiative.

– When an equipment is not functioning, they call in the e-waste recyclers to remove the equipment. The e-waste recyclers weigh the equipment and pay a sum of money as determined by the value of the waste. The disposal must satisfy audit requirements and must be undertaken in the most economically advantageous manner.

Unwanted IT equipment must not be abandoned. This includes broken IT equipment that must be recycled as e-waste.

Any university desktop or laptop which are to be disposed of to third parties MUST:

– For security purposes, be formatted and the original purchased operating system reinstalled, to ensure that all private or confidential information is removed, and software licence requirements are adhered to.

– Be branded as "disposed of by UCT" if the desktops or laptops have previously been branded as "UCT" to denote ownership.

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