E-Waste Management in a Global Digital Economy

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Abstract. Electronic waste, or e-waste, is one of the fastest-growing household waste flows. This is due to the raising popularity of electronic devices and ICT in human life coupled with their rapid obsolescence, which means that not only broken, but also fully intact devices quickly become useless. Electronic devices turn into waste while still usable because they no longer meet consumer requirements.

1. Introduction
The amount of electrical and electronic equipment (EEE), whether in disrepair or obsolete, is growing at an alarming rate. According to the United Nations University (UNU), some 44.7 million tons of waste electrical and electronic equipment (WEEE) was accumulated worldwide in 2016 and only 20% was disposed of. This means every human person on the planet generates approximately 6.1 kg of e-waste per annum [1, 2]. Asia leads in e-waste generation, followed by Europe, North and South America, with Africa running up. Europe leads in e-waste collection and disposal (35%), followed by North and South America (17%), and Asia (15%) [3, 4].

Electronics manufacturing is on the rise, and so is e-waste. Table 1 provides WEEE data on some of the world’s regions.

| No. p/p | Country/Region        | WEEE amount, thousand tons | WEEE amount, kg per capita |
|--------|------------------------|----------------------------|----------------------------|
| 1      | European Union         | 9,918                      | 19.25                      |
| 2      | USA                    | 9,360                      | 29.78                      |
| 3      | China                  | 7,253                      | 5.36                       |
| 4      | India                  | 2,752                      | 2.25                       |
| 5      | Japan                  | 2,742                      | 21.49                      |
| 6      | Russia                 | 1,478                      | 10.41                      |
| 7      | Brazil                 | 1,388                      | 7.06                       |
| 8      | Republic of Korea      | 961                        | 19.22                      |
2. Statement of problem

Electrical and electronic equipment (EED) is crucial to human lives today. One important reason why computer and office hardware needs to be disposed of properly is that such equipment contains precious metals, which have to be accounted. The unique properties of precious metals (PM) make them usable in a variety of electronics (household appliances, computers, cellphones, sensors, etc.) [6].

The focus on WEEE management comes not only from the valuable metals they contain (ferrous metals, aluminum, copper, cadmium, gold, silver, palladium, etc.), but also from the presence of pollutants that can harm the environment and deteriorate human health.

Obsolete or worn-out equipment such as phones, computers, TV sets, air conditioners, household appliances, tools and other automatic devices environmentally hazardous and health-damaging substances; they pose a grave danger unless disposed of properly.

However, many types of WEEE are not disposed of properly, if at all; instead, WEEE accumulates in landfills. There are only very few instances of WEEE management systems that seek to retrieve valuable recycled materials from them, including gold and rare-earth elements.

WEEE management is a three-stage procedure [4]:
- pre-dismantling and sorting of waste and its components;
- deep WEEE recycling to retrieve valuable materials;
- production of energy by incineration of burnable waste.

3. Theory. Legal framework and practices of WEEE management abroad

Europe, Asia, and the United States are adopting legislative framework to protect the environment and to manage the design, manufacturing, use, and disposal of materials in many sectors. However, these issues are most pressing for electronics, where the lifetime of a product is short, its costs are high, and the R&D/manufacturing/sales are done worldwide.

Japan and the European Union take the lead in adopting such new frameworks, although China and the United States follow up to tighten the requirements to EEE manufacturers. Since the market for electrical and electronic devices is global, the new frameworks apply far beyond national manufacturers, as any manufacturer of equipment or its components must follow the new rules. In practice, this means that environmental legislation becomes global [7, 8].

United States. 2004, California adopts its Cell Phone Recycling Act.
2008, first law is adopted to prohibit the export of mercury-containing equipment.
2010, New York is the 23rd state to adopt its Electronic Waste Recycling Act.
March 2012, the Executive Office of the President resolves that non of the e-waste generated by federal agencies shall go to landfills.

According to the Institute of Scrap Recycling Industries, ISRI, the USA recycled 4.4 million tones of e-waste in 2011 alone. Over 70% of that mass (ferrous and non-ferrous metals, plastics, and glass) was re-used to make new products. Mass-wise, the TV sets, computers, and computer displays were the bulk of recycled waste. Recycling involves up to 1,000 companies, 85% of which have less than 100 employees; in total, the industry employs more than 45 thousand persons. The industry generated about 5.2 billion US dollars in revenue in 2010 [7].

Japan. In 1998, Japan passed its own Home Appliance Recycling Law. The responsibility for recycling lies with the manufacturers. Logically, they now seek to make environmentally-friendlier products, as they will be cheaper and easier to recycle.
In 2003, the country adopted its Personal Computers Recycling Law; again, recycling is the manufacturer’s duty. A user can dispose of their computer by handing or posting it to the manufacturer.
In 2008, Japan proposed the New Zero Waste International Action Plan [7].

BRIC countries. China’s landfills accumulate about 2 million tons of refrigerators, computers, and sundry WEEE every year. In India, this figure is about 600,000 tons. Brazil generates about 680,000 tons of WEEE per annum.
3.1. Other countries

South Korea. The first waste management act was passed in 1992 (Act on the Promotion of Saving and Recycling of Resources). The act created a deposit system: manufacturers had to make a deposit in proportion to how much of this specific item had been released in the preceding year. Deposits would be refunded in proportion to how efficiently waste was collected and recycled. Deposited sums were set by the Ministry of Environment, while the Korean Recycling Corporation audited the recycling efforts and managed the non-refunded deposits. Gradually, the law was extended to washing machines, air conditioners, and refrigerators.

The Extended Producer Responsibility Act was passed in 2003 and amended the previously adopted act. The Ministry of Environment sets forth the recycling targets by product type, which vary from 55% to 70% of the product weight. The manufacturer has three options: to construct their own WEEE recycling facility; to make a contract with a recycling corporation; or join the Producer Responsibility Organization (subject to a fee). As a result of implementing the system, more than 40% of WEEE was collected and recycled by manufacturers in 2006 [7, 9].

Sweden. Municipalities provide recycling centers, where waste collection operators can set up their collection facilities for WEEE and used batteries. Operators pay municipalities at a rate of 0.03 euros per kg of collected WEEE. However, municipalities are not obliged to do so; contracts between municipalities and collection operators are subject to periodic review.

Municipalities collected about 90% to 95% of Sweden’s WEEE. Households are offered a variety of WEEE collection procedures, whether at convenient near-home points or at centralized locations. The WEEE collection fee is often included in the municipal waste tax households have to pay.

The national collection system comprises electrical and electronic equipment stores (all retail stores since October 2015), private companies and entrepreneurs (400 facilities), all of the country’s municipalities (600 facilities), and 10,000 battery collection points.

Any company involved in environmentally hazardous operations or applying for a license for such operations have to pay an annual fee to the Environmental Protection Agency.

Sweden has several WEEE management licenses. Dismantling and extraction of components for further recycling is subject to a C license; issuing it requires no extensive research, and the licensing procedure is fairly fast. Basically, the recycling company only has to notify the municipality before commissioning its facility.

Pre-processing WEEE storage is subject to a B or C license depending on capacity. If a company plans to store more than 50 tons of WEEE, it will need a B license, i.e. a written permit from the regional administrative council, which will set forth specific conditions.

B-licensing requires extensive research, including environmental impact assessment (EIA), consulting the locals, and comparative analysis of multiple available locations. The applicant must convince the authorities their operations will not jeopardize the environment or human health. Once the authorities are convinced, they will issue a permit specifying the mandatory terms and conditions (rules) [10].

3.2. European union

The European Union has a number of directives and regulations to prevent environmental contamination by waste electrical and electronic equipment [11]:

Waste Electrical and Electronic Equipment Directive (WEEE Directive) 2002/96/EC dated January 27, 2003;

Waste Electrical and Electronic Equipment Directive (WEEE Directive) 2012/19/EU dated July 24, 2012 [12];

Directive 2002/96/EC of the European Parliament and of the Council dated January 27, 2003 On the restriction of the use of certain hazardous substances in electrical and electronic equipment. It effectively bans the use of Pb, Hg, Cd, Cr(VI), brominated flame retardants, and polybrominated biphenyls and diphenyls (Restriction of Hazardous Substances (RoHS));

Directive 2005/32/EC dated July 6, 2005 On the Ecode-Sign of Energy-Using Products (EuP);
Regulations of the European Parliament and of the Council No. 1907/2006 dated December 2006 on the Registration, Evaluation, Authorization, and Restriction of Chemicals (REACH).

The directives are based on the Polluter Pays principle, i.e. the civil society capable of handling the situation is responsible for doing so. Practically, these directives:

- promote the design and manufacturing of electrical and electronic equipment for easier dismantling and recovery, with a focus on the reuse and recycling of waste, its constituents, and materials;
- mean the manufacturer assumes responsibility for its products, their recovery, and environmentally safe disposal;
- create a WEEE sorting, recycling, and disposal system;
- incentivize waste management companies that deploy certified environmental management systems;
- set forth clear WEEE recycling quotas that must be met by December 31, 2006 at the latest.

Depending on which of the 10 EEE categories an item belongs to, up to 80% of its average weight might be subject to recovery, while up to 75% of the mass of materials, components, and substances used in a product might be subject to reuse and recycling;

- provide for free-of-charge collection of e-waste from private households and distributors;
- ban some heavy metals and brominated antipyrines from use in electrical and electronic equipment;
- set forth that a EU-wide collection system be in place within 30 months once the directives come into force [11].

Notable is the European Union’s initiative to develop and implement an Integrated Product Policy (IPP) as a comprehensive tool that was adopted as far back as in 2003 and is currently furthered towards sustainable consumption and production. The IPP seeks to support sustainable development by reducing the negative environmental impact over product life cycle. It is generally based on the following fundamental principles:

- instilling life-cycle thinking into stakeholders by shifting the focus from local sources of pollution to monitoring the environmental impact over the life cycle, including safe disposal of used products;
- using the various IPP-provided tools, including economic incentives, administrative bans, voluntary agreements, eco-labels, eco-design, etc., to match the product diversity.

The WEEE Directive specifies 10 WEEE categories for reporting [11, 12].

- Large household appliances
- Small household appliances
- IT and telecommunications equipment
- Consumer equipment
- Lighting equipment
- Electrical and electronic tools
- Toys, leisure, and sports equipment
- Medical devices
- Monitoring and control equipment
- Automatic dispensers

Russia still lacks any legislative framework like that.

**Global Experience as a Foundation for Russia’s Legislative Framework and Action for WEEE Management (collection, storage, transport, dismantling, use, recycling, and documentation of actions).**

To date, Russia’s legislative framework has had nothing similar to the European WEEE and RoHS directives to limit the use of potentially hazardous elements in EEE. E-waste management in Russia boils down to singular manufacturer initiatives, the first steps of NGOs, as well as disposal legislative initiatives. Given that the demand for, and supply of, electronics is on the rise, so is the amount of e-waste, meaning the e-waste recycling and disposal become increasingly critical. UNIDO experts have
been tasked to find why the existing systems cannot cope with the looming threat and what has to be done [7, 8].

Russia’s waste producers and recyclers rely on the environmental law, in particular the Federal Law No. 89-FZ dd. June 24, 1998 On Production and Consumption Waste; and No. 7-FZ dd. January 10, 2002 On Environmental Protection; however, neither law details e-waste management.

The current legislative framework provides three options for importers and manufacturers to manage waste:

- pay an ‘environmental fee’ to the state;
- dispose of unusable and used appliances independently;
- join their disposal efforts.

The Waste Electrical and Electronic Equipment Recyclers Association (WEEERA) unites all the major appliance manufacturers and importers; the Association makes active use of the disposal laws and seeks to update them. Many of its participants do not collect and recycle used devices independently, as that will require a special license. This is why an association or disposal fees are the more feasible options as of today.

Rosstandard has attempted to modify the legislative framework to handle the situation; its only output so far is GOST R 55102-2012 Resources saving. Waste treatment. Guideline on the safe collection, storing, transporting and disassembling of the waste electrical and electronic equipment except mercury-containing devices and appliances [13].

The standard provides guidelines on the safe collection, storing, transporting and disassembling of the waste electrical and electronic equipment except mercury-containing devices and appliances. It does not apply to military waste, nuclear safety waste, and space equipment.

The GOST defines the term ‘waste electrical and electronic equipment, WEEE’ as waste, unusable, or obsolete electrical and electronic equipment, including its assemblies, parts, and components. WEEE comprises the categories listed in Annex A (10 WEEE categories per the Directive 2002/96/EC) of equipment designed to operate at 1,000 VAC or 1,500 VDC at max., as well as any and all assemblies, parts, and components of such equipment.

The standard divides WEEE into two many categories:
- reusable WEEE;
- WEEE that can be recycled to retrieve materials and energy.

GOST R 55202-2012 vests the following economic actors with the powers to collect, store, transport, and dismantle WEEE:
- manufacturers of electrical and electronic equipment;
- WEEE recyclers;
- specialized WEEE collection and storage facilities;
- recyclables collection facilities.

The standard goes at great lengths to detail the procedures for the collection, storage, transportation, dismantling, and documentation of WEEE [13].

In general, the standard is expected to become crucial to organizing and guiding the WEEE management efforts; however, the Federal Law No. 184-FZ dated December 12, 2002 and effective since July 1, 2003 On Technical Regulations states that only the technical regulations can set forth mandatory safety requirements, while the state standards are voluntary to follow; this means that users’ awareness of this document and the WEEE recyclers’ willingness to apply its requirements, as it had used to be done before Russia’s standardization system was reformed, will be of paramount importance.

According to the UNIDO Project Coordinators in Russia, the country lacks any integrated system to collect and dispose of WEEE country-wide. Every year, up to 70 million units of electronics and electrical equipment is marketed in Russia. Research shows the nation has only a few dozens of small recycling companies scattered around the country.
They mainly retrieve precious metals for sale to PM refineries. They also sell the resulting ferrous and non-ferrous scrap. Russia’s major EEE chains Eldorado and M-Video’s WEEE management programs, although quite efficient at WEEE collection, are mainly marketing moves.

Manufacturers are not engaged in recycling, and they are not going to be unless amendments are made to the Federal Law No. 89-FZ dated June 24, 1998 On Production and Consumption Waste to effect extended producer responsibility for the post-service life disposal of their products [7].

What are the Realistic E-Waste Management Scenarios?

UNU looks into four e-waste management scenarios [14].

The first, best-case scenario is that manufacturers, sellers, and local self-governments will arrange a controlled procedure to withdraw e-waste from households. Each component (precious metals, plastics, chemicals in batteries, etc.) will be recycled separately and then return to production.

This scenario can deploy the following chain: users from all sectors of economy (private, commercial, industrial, and institutional users) collect waste as part of household or municipal collection efforts, or using waste collectors’ and professional waste facility operators’ services; the waste is consolidated, recycled by components and materials to process, extract, and dispose of hazardous waste; useful matter are retrieved and return to manufacturing as recycled materials [15, 16].

The second scenario is to dispose of e-waste in the same way as, and together with, sundry solid waste. However, EEE contains toxic components that accumulate in landfills and poison the environment; new toxic compounds may be released if due disposal procedures are not followed.

The third scenario is that e-waste be collected by private companies. Private operators will be able not only to collect EEE for recycling, but also to refurbish or repair it for sale in the second-hand markets domestically or in the developing countries.

The fourth, worst-case scenario is that private companies collect e-waste for disposal in third-world countries. They dismantle the equipment and throw away the unusable parts, which jeopardizes the environment.

According to Rosprirodnadzor, the bulk of WEEE remains in storage. Federal Law No. 309-FZ dd. December 30, 2008 On Amendments to Article 16 of the Federal Law On Environmental Protection and to Certain Other Acts of the Russian Federation introduces the concept of six-month waste storage [6]. Companies need no permits to store waste up to six months, which is why over 50% of waste is labeled as ‘in storage’. So even the official reports confirm that only a small portion of WEEE actually goes to recycling and neutralization. In 2013, 5% of officially declared WEEE was recycled, 0.001% was neutralized, and 2% was buried despite bans.

4. Conclusions

1. Russia needs a WEEE management system that will handle e-waste separately from other wastes and will provide e-waste sorting procedures based on the best global practices [17], recycling, and funding for recyclers before extended producer responsibility is set forth legally.

2. The existing Law on Production and Consumption Waste needs to be amended in the context of WEEE-specific management requirements; an alternative solution would be to draft and pass a new Law on Waste Electrical and Electronic Equipment [18, 19].

3. The WEEE management frameworks to be developed must build upon the experience and practices, research and development efforts of the European Union, China, Japan, and the US with adjustment for the country’s actual economic models and situation [9-12, 16, 20].

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