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Chapter

Renovation and Reuse of Waste Electrical and Electronic Equipment in the Direction of Eco-Design

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Abstract

Nowadays there is a higher need of strict and broader legislation in waste electrical and electronic equipment (WEEE) recycling industry to reduce environmental effects of WEEE. Environmental challenges include pollution, exhaustion of natural resources, waste management and reduction of landfills. High speed in technological development in many sectors puts many products in great challenge of obsoleting almost immediately after their purchase. In particular, this is the fate for electrical and electronic equipment (EEE). They are forever-improving and incorporate state of the art innovations. This provide many benefits; however, at the same time, its expansion results in rapidly growing waste stream of WEEE. WEEE contains a combination of all these situations, including for example, batteries, plastics of quality, precious metals and toxic soldering metals. The reuse and renovation of WEEE are therefore very critical because of its significant ecological environmental impacts. Sustainable development is not a static situation, but a state of dynamic balance between human and environmental system. The current chapter explores sustainability planning and strategies such as eco-design, and design for dismantling and recycling, and what they mean for electronic products. It examines the incentives, methods and tools for sustainable electronic product design, with particular emphasis on reuse, recycling, selection of sustainable materials and processes, and lack of resources.

Keywords: WEEE, eco-design, reuse, recycling, DFS, reconstruction, renovation, repair, life cycle

1. Sustainable construction, planning and development and reuse procedures: design for sustainability

WEEE production is growing every year [1]. However, the product life cycle analysis demonstrates that disposal phase contributes substantially on the environmental impacts of WEEE [2–4], especially in products containing toxic materials, rare or valuable materials, or materials with high energy content. The world's current experience of financial crisis and climate is a major crisis nowadays that seems to be linked. With implementation of improved regulatory and control mechanisms, avoiding future financial crisis is possible, while scientists predict no regulation will save the planet from devastating consequences. Climate change further than environmental issues has serious social implications, from displacing people from areas they lived for generation to rising food prices. In addition, it will create economic threats in many countries that are comparable in size to world wars [5].

There is a third serious crisis that we are already facing: the exhaustion of limited natural resources. Finishing mineral oils is well known, but other natural resources too, for example, rare earths and precious metals. Nowadays, the objectives of wars and conflicts are land, water, food and mineral resources, and it is a proof that production and consumption have reached saturation point that cannot be a model of growth for a planet that will reach 9 billion in 2050. Despite efforts, industrialized countries consume 70% of global resources and host only 20% of world's population. Three sectors of consumption are primarily responsible for this: food/agriculture, transport/tourism, housing/energy consumption in buildings. These sectors account for about 80% of environmental impact of EU countries [6].

Brundtland Commission formulated "Sustainable Development" model in 1987 [7] as a development that meets needs of present living generations, without compressing the ability of future generations to meet their needs. In 1992, more than 170 countries agreed to fight for sustainable development as set out in Agenda 21 [8], where specific work on production, consumption and policy is formulated, and possible meters are proposed. Despite the breadth and complexity of the issue, these six key principles describe how a viable community should interact with other communities and nature:

- Protection of the environment: Protection of resources and life support systems needed to maintain human well-being and life.

- Development: Improving "quality of life," whose economic growth is a part of it, not a single objective!

- Future: It takes into account the interests of future generations in relation to what we leave behind.

- Equality: Fair distribution of resources, between developed, developing and even least developing countries (as each has a role to play and a cost to pay) in transition to sustainability. In particular, the most vulnerable (least developed countries) should be top priorities.

- Diversity: Different environmental, social and economic systems are generally more powerful and less vulnerable to irreversible or catastrophic damage. It is also a choice to more sustainable choices.

- Participation: Sustainability is not imposable; it requires support and involvement of all society's sectors and communities. This requires ensuring opportunities for participation in decision-making process.

1.1 Characteristics of sustainable development

- Conservation of resources

- Respect for the views of all interested parties

- Cooperation and partnership

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- Follow-up to the precautionary principle
- Encourage subsidiarity: make decisions at the lowest achievable level
- Promoting personal freedom: satisfying needs without harming the environment or people
- Esthetic treatment: protect and create beauty spots and items

The term "sustainability" has been introduced by Victor Papanek in his publications [9, 10]. Already significant networks, including the environmentally friendly-designing international O_2 network (www. o2.org), established as early as 1988 [11] and, even more lately, the biggest networks and design establishments, have been effecting to introduce sustainability-design practices (DFS). Although there is still a lot of surface debate and some initiatives, especially from big companies, can be detected as green "laundering" (false or excessive green claims in advertising without real action), the current trend with DFS is constantly increasing.

With small efforts in research, it is apparently lagging behind in current development and market demands of DFS professions, and the few available programs for the growing number of young and enthusiastic students who they want to engage in DFS. Designers in broadest sense, including engineers and commercial creators, are still very often part of the current sovereign economic system, aiming at quantitative development as the sole objective of encouraging growing consumerism and wastage due to disposable products. These cause massive flows of resources from nature to waste disposal areas within a shockingly short period of time and the sale, through advertising and communication, of "goods" that you do not need but promote a modern useless lifestyle as the only desirable model of world prosperity.

Furthermore, engineers and scientists are not often strategic decision-makers and operate just at the bottom of the command structure. Sustainable development managers need to sit at the decision-making desks to push a real change. They need to be "loaded" with expertise of sustainability-based research and evidence, but also methods for evaluating and directing development and evidence-based planning decisions. They need to know about the history, problems and motivations of DFS theory and practice, and should adopt a more participatory practical design by first listening to stakeholders, understanding their problems and motivations, and then trying to develop more sustainable solutions [12].

2. Sustainability and eco-design of EEE with reuse of parts and materials

2.1 Reuse of parts and materials

Generic reuse strategies (include recycling, repair, rehabilitation and rebuilding) all are important strategies for sustainable production, because they help reduce landfill and the need for new material to be used in production. Rebuild, reconstruction and restoration (also referred to as recycling of products, commodity recuperation or resale market functions) are the various manufacturing techniques that use elements from used materials and are advantageous for recycling (recovery/reuse of content). Recycling defines the number of activities that gather, identify, process and use recycled materials in the manufacture of new products [13]. The advantages of restoration to recycling typically involve the following [14]:

- Reconstruction is a practice of “addition,” whereas recycling is just a method of “lowering,” so restoration of the material increases the value to the waste by converting it to functional condition. But at the other hand, recycling decreases the commodity to its raw resources.

- Reduction (which was) used in the manufacturing of the original material will be wasted after recycling it. The objective of this is to restore as complete as feasible the consumer goods, thus keeping energy and incoming resources of their first construction. However, recycling loses most of this energy and resources through reduction in raw materials. And this loss is even greater if energy used to extract raw materials and transport them is taken into account.

- Using the raw material recovery strategy, the waste of energy and assets to extract a marketable product from the waste product is greater. This may be because twice resources are expended on the processing of raw materials. Essentially, the product is “reduced” to resources (e.g., pouring smelting) but also, afterward, the resurrected materials are turned into goods.

- Engineers might be hesitant to using recycled materials since their performance could be uncertain [15]. Reconstruction is typically much more efficient in bulk material restoration than recycling, particularly for structural and electromechanical massive and complex materials.

The decision to implement product recovery should be carefully considered, as it may in some cases be counterproductive to sustainable development, for example by helping ineffective products to remain in circulation longer than is desirable. This is the case when a newer generation of products tends to be more environmentally friendly and efficient in operation; for example, new technology washing machines usually require less water, detergent and electricity. It is better that ideal product recovery is being used when it is both profitable and beneficial to the environment. Other issues to consider include creating new business models that include an effective reverse logistics system and ensuring sufficient quantities of used products (cores) to support product recovery processes. This is particularly important as consumers will only buy recovered products if they are considerably less expensive than other new products [16]. In the example of residential commodities, guaranteeing sufficient distribution of product is especially challenging, as it cannot be defined when these consumer goods will complete their lifespan. Optimally, commodity recuperation operations must be focused on eliminating substantial greenhouse emissions from the conveyance, as sections of the cycle actually occur at separate locations or, worse, when the waste material is shipped for processing and afterward brought back for purchase into the home country. There is a ranking predominantly centered on quality within a material recuperation method. Restoration is at the peak of this ranking since it’s the only method of commodity recuperation that can return discarded goods in terms of quality, reliability and consistency to a standard competitive to that of new alternative commodities.

2.2 Sustainability and eco-design of EEE

Sustainability and eco-design of electrical and electronic equipment can be achieved by consumer awareness and the search for sustainable solutions, the requirement for legislation that ensures greater producer responsibility and green-sustainable programs, ensuring a competitive advantage for companies leading such efforts, the development of social responsibility and the need for business owners and consumers to invest their money and whatever that is reasonable and useful for people and the planet.

The EU's most important legislative instruments on the design of electrical and electronic equipment aim to save energy, manage the end of life and resource efficiency as key issues. The key legislative acts are Directive 2002/96/ EC on WEEE and Directive 2002/95/EC on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS). The WEEE and RoHS Directives are indicative of a policy strategy of boosting manufacturer accountability for recycling and management funding, reduce the environmental impact of electrical and electronic equipment and promote the recycling of valuable resources [17].

In conjunction with both the WEEE and RoHS Directives, Directive 2005/32/EC [18] laying down a guideline for establishing environmentally friendly design requirements for EUP is also significant because it spans the entire life cycle of energy-based products and the establishment of particular environmentally friendly design requirements for specific product groups through stakeholders involved in consultation processes. After end-of-life issues have been addressed with the WEEE and RoHS Directives, environmental significance of use phase due to energy consumption has also become evident in relation to increase in climate change threats. Thus, EUP Directive predicts energy efficiency of electrical and electronic products. However, additional design requirements for certain products (e.g., dishwashers and washing machines) that consume water and detergents during use phase are addressed in EUP reports and documents [19] and items with an impact on power consumption namely insulation, window frames, waterproof illumination, etc. The important regulatory platform is the current waste class division implemented in the European Waste Directive, which encourages waste reduction and preservation and whether products and resources are circulated. This would also influence design specifications, such as easy access to useful materials and competitive recycling capability, including recycling technologies. That package of all these four guidelines may be regarded as an attempt to achieve the European Integrated Policies Policy (IPP) goals.

Strong policy instruments to support sustainable planning activities also include the so-called green public procurement (GPP) or sustainable contracts. The public sector typically accounts for 10–20% of GDP, and annual investment from public procurement alone in the EU amounts to 72 trillion or 17% of GDP [20]. The "green procurement" has a growing importance in Europe. However, its pace of implementation varies considerably between various European countries. Current developments in EU policy and the EU 2020 strategy [21] further strengthen ambitions in the field of green public procurement and their implementation in practice. Most EU Member States have adopted national action plans for sustainable procurement, including objectives and implementing measures. An important factor in eco-design is ecological and communication labels, which remains a useful tool for rapidly exchanging information along the supply chain and between consumers. The most eco-labels for electronic products include the Nordic Swan, the Blue Angel (Blaue Engel) and the American Energy Star Label, the EU eco-label or the various energy efficiency labels defined in the EU Member States for specific product categories, such as large household appliances [22].

Simultaneously, policymakers, manufacturing firms, customer groups, journalists and also investors are increasingly seeking data from end-users, manufacturers and retailers regarding environmental consequences and sustainable development. Therefore, it is very significant to be able to track the products and their components to the original source throughout the entire supply chain. It is compulsory for those who import consumables into the EU market and their suppliers to provide data on adherence to EUP specifications. Across the USA, government requires corporations to use industry consultants to guarantee that their raw materials are not troublesome [23]. The problematic metals are widely used in electrical and electronic equipment (e.g., tantalum, gold, tungsten and derivatives). This requires the management of information along the supply chain, the standardization and digitization of relevant information, and respect for the confidentiality and competitive advantage of this information.

With regard to the standardization of EEE products, many national and international standards relate to sustainable design. International Organization for Standardization (ISO) published in 2002 a technical report ISO/TR 14062 [24]. This report refers to methods, tools and best practices for integrating environmental aspects into product design and development. It is currently being transported to ISO 14006 for the implementation of eco-design in Environmental Management Systems under the ISO 14000 series (ISO 14006 [25]). Although neither the technical report nor the new standard is intended to be used as standards for certification and recording purposes, certification bodies and companies have already used them for labeling activities, for example, environmental statements for cars, such as KIA [26] and Daimler [27]. As consumer demand for sustainable products is constantly increasing, new research bodies with ecological and social consciousness, for example, the Sinus Institute Heidelberg [28], describe consumer behavior.

3. Comparing reuse options; reconstruction, renovation and repair, including planning principles for sustainability

These three major recycling possibilities aren't in fact equal, but rather a ranking exists among them, with reconstruction at the highest level, then restoration, and finally repair. Reconstruction is a practice of upgrading a used commodity to a minimum to the new product quality requirements and providing the resulting product a warranty that would be at least on par with that of the new produced alternative [29]. At present, reconstructing is typically profitable for large and complex mechanical and electromechanical products that follow an extremely stable technological process and for materials and components that are expensive to manufacture or can become expensive in the future. The value of component reuse in relation to dismantling costs makes manually dismantling these products worthwhile, allowing the reconstruction of profitable products. Reconstruction can be differentiated from repair and renovation, at four key points:

- Reconstructed products have a guarantee equal to that of new alternatives, while repaired and renovated have lower guarantees. Typically, with the renovation, the warranty applies to all important parts that are damaged, and the repair is only applicable to the repaired part.

- Reconstruction requires more effort than the other two methods, with the outcome that the standard and efficiency of its commodities appear to be greater.

- Reproduced devices lose their identities when rebuilt and refurbished maintain their own as all parts of a commodity are recycled in the reconstruction and new ones are replaced by people who can no longer at minimum return to their initial standards.

- Reconstructing may include upgrading the product used beyond its original specifications, which is not the case for repair and renovation.

The main advantage of reconstruction is that it allows to combine the low price and good quality of the products, especially when the reconstruction also involves increasing the performance and quality of the products used beyond their original standards when these were new. Xerox is a typical example of successful reconstruction since its copiers are typically subjected to seven life cycles. This means that seven revenue streams are generated from the construction of a single product, and materials are diverted from landfill or recycling at least six times [30]. The disadvantage of reconstruction with regard to smaller product recovery processes is its higher cost because of the more resources used and most of the work required to get the reconstructed product.

Thus, there are many products where the reconstruction would have a prohibitive cost given the current reconstruction technology and the basic knowledge required. Major home appliance manufacturers, such as Lec Refrigeration and Merloni, implicitly suggest that rebuilding of household appliances has a prohibitive cost, at least within EU. The main reason is cost of manual labor involved in reconstructing and additional costs, such as costs for testing with safety standards that are accurate. Cost of these tests in new production can be limited by "run" per batch, but in reconstruction, tests have to be done individually.

3.1 Planning principles for sustainability

Several basic rules of sustainability management can be enforced to all types of commodities, including electrical and electronic equipment. These can be illustrated as follows:

- A real issue, originating from an actual problem and working on solutions that are culturally, ecologically and financially advantageous
- Research, specifically, of processes and facilities, not commodities, such as not beginning with the development of a washer and dryer, with the air to satisfy consumers but finding environmentally friendly ways of cleaning clothes
- Participation of users, operators and various experts in design process as much as possible
- Attempting to investigate all the different dimensions and criteria, as well as prioritizing hierarchies according to the timing and scope of the project

3.2 Life cycle consideration

Considering that the lifespan is an integral and absolutely essential aspect of DFS, this covers all aspects of the lifespan of a product, from resource extraction to the phases of use and end of life. In this sense, policies for reuse and recycling including biodegradation, incineration and final disposal are being introduced. DFS seeks to continually improve the sustainability of the entire system at all levels of the lifespan of the commodity, such as removing harmful chemicals, improving efficiency and performance, promoting reuse and recycling. In addition, DFS analyzes the context of use and the systems in which products and services are added to the life cycle with the prospect of a sustainable product-service-system design [31]. When designing sustainable product service system, the whole mentioned system will be considered.

3.3 EEE usage phase

The minimization of energy during the use of electronic products is the main objective of the EUP Directive. The EUP criteria for the different product categories cover for example the energy consumption during the use of the appliances and the standby power consumption. Although energy consumption thresholds are mandatory for all products covered by the Directive, no design strategies or additional measures to encourage the so-called sustainable user behavior are defined.

Therefore, the use process consists of several phases, such as commodity acquisition, start-up, utilization, maintenance restoration and recycling, and consumer attitudes at any stage that is hard to anticipate. During the engineering process, extra effort should be undertaken to influence customer behavior, for example, to provide characteristics and data through the packaging in the commodity and customer information to cultivate customer's economically viable attitude.

Design strategies for optimizing the use phase include the following:

- Knowledge delivery, support infrastructure and possibilities for environmentally responsible use and recovery after use

- Maintenance operations architecture

- Incorporation of functionalities to reduce power expenditure (e.g., the display of vacuum cleaner effectiveness data—indication signal in case a filter change is required)

- Inspiring and persuading buyers to reconsider their practices, such as not using dryers and drying clothes outside, laundering only under maximum load and at lower temperatures, etc., and additionally marketing them in an enjoyable and pleasurable manner, or issuing customer and group rewards [32].

4. Repair of products in industry; tools and rules for sustainable design

4.1 Repair of products in industry

One of the most typical product repair applications, which will be discussed in this section, is that of computers. The repair of computers and other office products, such as printers, has been going on for over 20 years and is not guided by the original manufacturers but by independent experts who have identified a commercial opportunity. Most manufacturers do not yet have the repair as a priority for serving their customers or the market, so demand is still met mainly by independent providers. Reopenable computers and print products can generally be categorized into three categories: repaired, renovated and reconstructed. There are currently a growing number of manufacturers who have put in place procedures to provide second-hand equipment to their customers, with some using "home-based" services and others involving independent experts as service providers. In the absence of legislation and standards, acceptable practices will be different among all suppliers of second-hand equipment (whether manufacturers or specialists), but the following descriptions provide a guide to product expectations within the three categories and throughout the computer market.

4.2 Tools and rules for sustainable design

To facilitate sustainability planners, there is already a wealth of tools and methods available to help integrate the environmental, social and economic aspects of planning processes. The most complex tool is Life Cycle Assessment (LCA), and the simplest are the rules of thumb that experts have formulated to give guidance to the design process. Through cumulative knowledge acquired for decades, various thumb rules have been developed concerning the following:

- Longer-lived products that consume significant amounts of energy, fuel, water, and other consumables that, during their lifetimes, very often, have significant environmental impacts occurring during use phase (making the reduction in consumption during use phase)

- Longer-lived moving products, for example, energy-consuming vehicles in practice, where the weight and other effects on energy consumption in the active/in-use phase are usually more important and consumables, for example, products with a very short life span that are lost or dissolved during use, where it is important to be non-toxic and biodegradable

5. Reusability and after that

5.1 Repair

Any fault or damage intervention, identification and correction is called repair. A mechanical or electrical repair will return a commodity to a working state, while a decorative repair can inflict cosmetic damage to the outside appearance and/or spots (e.g., crack, stain, scratch or rupture). A certified technician or a service center could restore a commodity regionally of the manufacturer or specialist. The test is only performed to ensure that the repair has eliminated or corrected the particular defect identified. Repairs are inherent activities in more extensive repair or rebuild processes.

5.2 Renovation

Renovation is one of the two processes associated with most reused products. It is carried out in a factory with functional specifications, involving a larger set of tools, cleaning solutions, solvents, paints and other surface treatment options. The upgrade is described as the return of a used product to a performance or quality greater than it was when it was brand new. While the refurbishment process does not seek to increase the original manufacturing capacity of the product, larger spare parts may be added if genuine spare parts are no longer available, or later higher-capacity components are of comparable cost. A refurbished product generally has a limited warranty, depending on the supplier (original manufacturer or independent specialist).

5.3 Reconstruction

Reconstruction is more complex than refurbishment and is a thorough, complete dismantling and reassembly process that returns a used product at least to the originally determined state. Depending on the processes of the remanufacturer (either original manufacturer or independent specialist), the disassembly process can either preserve the identity of the original product (through serial number) or provide a completely new identification system (supported by a new serial number).

Reconstruction includes detailed cleaning, testing and diagnosis of all dismantled parts. Components, depending on their commercial viability, are either repaired or replaced. Repairs to components or sub-assemblies are performed by the remanufacturer or shipped to a specialist on the product. Upgrades are also provided for parts of the hardware when commercially available, and any other changes to the software or logistics infrastructure should also be included in the rebuilding process.

Restoration is conducted at a factory location with appropriate sets of equipment and measurements similar to that used in initial production with guidance found in the method of audit documentation. Due to the complete removal of the items, the factory default configuration must be deleted or modified. Furthermore, new additions and improvements can be introduced in order to provide commodities with the latest available innovations compared to standard prototypes. Refurbished commodities can, therefore, be identical to current production versions, checked at the same standard, and commonly sold as "new" with a complete or revised insurance.

It has to be mentioned that the standard engineering term of reconstruction in the field of information technology is more like rebuilding, as very few are actually reconstructed in the same way a component was originally constructed. Most computer and printer vendors will use specialized manufacturers to build key components and subsystems (such as processors, memories, optical drives, and hard drives), and the cost of replacing with a modern component is generally lower than repairing older defective product.

5.4 Upgrading

Repair can be part of the renovation or rebuild process. Upgrades can be developed to meet customer-related issues, or programmed events in the product life cycle, especially when the product is complex and designed for long service life. Improvement tends to increase or boosts the efficiency of the device by upgrading its capabilities or performance, along with changing or incorporating components or modules to enhance the capabilities of the original model. Just like the repair, the examination is minimal and then only to ensure proper implementation and operation of the improvement.

Several adjustments may improve the item's capability further than the level of initial manufacturing processes, and some may even push a commodity to the latest model standards. It is dependent on an item's evolutionary interoperability that relies on the prototype technical adaptability and the ability to improve a model throughout its lifespan.

Improvements could also emerge from the absence of the initial product, which may result in improvements caused by a lack of option in repair and refurbishment.

5.5 The secondary product market

While the reconstruction of electrical equipment cannot mitigate ecological advantages and competitiveness, it can be accepted regarding social aspects such as addressing inequality, unemployment and absence of qualifications. The policy choice to be decided throughout the context of second-hand trade functions for some types of commodities such as home equipment should be whether or not ecological issues and their decreased productivity can be overcome by their tremendous social gains and re-operating ecological gains. Therefore, the ecological risks are likely to overshadow the significant social benefits. Some socioeconomic positive effects of resale business operations comprise employment advancement, improving the overall professional career for the regional society and individuals reselling second-hand consumer commodities, supplying basic goods to disadvantaged people who would otherwise be unable to access them, and providing with employment access to unqualified individuals. The socioeconomic consequences of resale business procedures may be defined via the efforts of several associations working with homeless people and several marginalized communities (https://emmaus.org.uk/) [33]. Organizations get donated products that are re-running and help the homeless to reopen them under their supervision. Their key advantages include the following:

- The homeless benefit from having a roof above their heads, paid employment, self-confidence and new skills that will help them start over.
- Organizations continue their various charitable goals.
- Jobs are created for the technical staff that oversees former homeless people.
- Poor people benefit because they can afford the purchase of goods.
- Jobs are being created.

5.6 Variability of standards and quality of renovation and reuse

Despite the fact that there is EU legislation for processing commodities that have reached the end of the lifespan stage, EU legislation does not exist today. Neither are other wealthy nations or areas motivated toward refurbishment or reconstruction to recycle IT commodities. Existing WEEE regulations include obligations and standards for optimal material recycling after it has been marked as scrap, but still there is very little to direct consumers as well as producers on reuse or prolonged utilization.

Without the regulations, the system of manufacturing requirements is very minimal and there are variations in the rate of re-operation and production quality with almost all of the construction in the control of autonomous professionals. Autonomous dealers, motivated by market opportunities, may very well typically try relatively cost-effective options to bring a device to function because then they can take advantage of a secondary efficient lifespan, resulting in competitive and dynamic business availability. Certain industry associations representing manufacturers and independent suppliers have tried to clarify the process, but are currently not developed in recognized national or international standards that can be independently controlled to provide recognized levels of accreditation.

5.7 Qualitative criteria for reuse and certification of reuse centers

As previously stated, in the sector of discarded IT appliances, there is little legislation, so specifications and standard requirements differ for all vendors on the sector of old IT hardware. The simpler present legal system applies to the purchase of goods, acknowledging that a commodity should not be altered and needs to be in line with the specific intent and characterization. Most of the items sold in stores are therefore defined as being partly “used,” yet without more explanation. By identifying their commodities as former-approved, certain vendors would only further distinguish their offers formerly-declared, formerly-borrowed, etc. This is generally the case for the newest used equipment below 12 months. Occasionally, some manufacturers sell excess product or product inventory through their used product channels and at lower prices, even if they are not open or new.

Some suppliers and broader individual distributors can mark their commodity rebuild procedures with some other industry certifications, such as international standards ISO, CEN, or national standards such as BSI or DIN. In particular, in the UK, BSI offers a protocol that includes descriptions and guidelines for the repair and future sales of used IT appliances [34]. This template has the acronym MADE (made for assembly, disassembly and end of life). This includes descriptions of procedures for re-assembly levels and re-launch of the equipment back to the market. At present, this standard serves as a voluntary industry guide without any certification or accreditation procedure that will confirm the correct practice by the supplier (be it manufacturer or independent).

Many of the suppliers of used equipment also have a waste permit for their reprocessing facilities to ensure compliance with legislation and to properly dispose of the waste generated in the re-operational processes. As with some repair work, some suppliers of used equipment may outsource the recycling operations to third parties.

6. Design issues in reconstruction and for reuse and recycling of EEE

6.1 Design issues in reconstruction

Improvement of refinancing and refurbishment would require changes in the architecture of the product as the architecture is the lifespan characteristic of the commodity that has the greatest influence on ecological burden [35] and also defines the commodity's capacity. That is, it will immediately raise the particular product cost and it will initially be costly but it will lead to long-term sustainability, bearing in mind the relative cost of waste management and many other environmental requirements. One major problem at this point is the lack of know-how of designers for designing products for reuse. A key issue in product design for reuse is to avoid features that prevent the product or component from being returned at least in its original state of operation. These include the following:

- Non-lasting component that may result in rupture during reconstruction (construction, maintenance or upgrade) as well as a limitation during use to the degree that the commodity is inadequate for "refurbishment"

- Involvement of techniques that prohibit element isolation or are likely to result in element destruction during separation: epoxy resin welding, for example, can be used to promote fast assembly but will prohibit disassembly without harm, leading to an increase of even further innovation in recycling or reuse

- Characteristics involving banned elements or techniques of storage or anything that might constitute the process costs unviable economically

Several of these main refurbishments and reuse considerations, though, bypass the influence of the manufacturer. The most critical of these are the rules, demands and restriction procedures of factories. Laws and regulations will have a significant impact as they allow businesses to raise the value added of their commodities and increase the cost of disposal. This can also motivate companies to produce refurbished commodities. Furthermore, if laws prevent the use of a chemical, the products that contain it cannot be re-imported into the marketplace and thus will not be reused. Refurbishment and reuse are only acceptable if the revived item has a demand. Fashion-affected goods are improper since consumers may choose the latest offering irrespective of the refurbished's price and quality. Many consumers demand modern goods as fashion options, so goods are usually less attractive in terms of renovation and reuse, particularly those that require a fairly low preliminary cost or are in prestigious positions in residences. Manufacturers' prohibitive practices, such as patents, property rights and anti-competitive processing, also prevent refurbishment and reuse. For example, some printer manufacturers have designed the ink cartridges to self-destruct when they are empty, thus preventing their rebuilding. However, if the old products do not exist to get rid of them or take good aspects of existing second-hand products, then the technology to produce new parts becomes obsolete, and therefore refurbishing the product will be impossible.

6.2 Design for reuse and recycling of EEE

According to the EU waste hierarchy, the mandatory priorities for EEE are prevention, reuse, recycling and other forms of recovery and finally disposal, if economically and environmentally feasible.

WEEE regulations also contain a strict requirement to promote consumer reuse and recycling pursuant to Section 4: Product Design. Member states are obliged to take action to stop manufacturers from the use of particular design characteristics or particular production processes unless such characteristics or processes are legally required or the actual advantages are immensely beneficial. In product design, to consider whether any of these approaches is most effective, the options for reuse of an item should be analyzed and correlated to raw recycling and dismantling policies.

The concept of reuse may include either individual components or the whole of the product, depending on its age and condition. Reuse can take place for the same purpose in the same system or to serve another purpose. During the design of the concepts or possibilities for reuse, the following criteria must be taken into account [36]:

- Technical criteria
- Quantitative criteria
- Economic criteria
- Time criteria
- Innovative criteria
- Delivery criteria
- *Criteria* for the compatibility of reusable devices with the standards of new EEE
- Other criteria, for example, market behavior, obligations, patents and property rights. Design strategies that support reuse and recycling include:
- Structured design and standardization of components
- Longevity design
- Design for recycling. Selection of recyclable materials, low material diversity, low toxicity, marking of materials and ease of dismantling:
- Recovery of valuable materials in electronic products

- Disassembly of components containing dangerous substances
- Disassembling components that obstruct recycling technologies upgrade planning. It includes technical upgrade
- Design dismantling and assembly
- Design concepts that make wear and tear of parts detectable and visible.
- Provision of instructions and information on recyclers and disposal instructions for end users
- Design of product-service systems. Maintenance, recovery and repair, lease upgrading, leasing, exchange, centralized services

All these strategies have as a common feature that they are very dependent on the systems around them. Waste, waste management and logistics systems affect recovery and reuse rates, while end-of-life design requires real planning elements and communication with the end-of-life industry.

Recycling is usually the ecological goal as it preserves the assets (materials and energy) expended in the commodity throughout production. This is accompanied by the recovery cycle recycling of parts and components. Such techniques include dismantling that is non-destructive. The most standard procedure at the moment, however, is product recycling whereby resources are acquired and structural specifics are destroyed. This technique makes catastrophic modification feasible and is a standard procedure for retrieving precious materials, for example, platinum and gold.

The life cycle reuse and recycling methods of a material can be applied as follows:

- Improve consumer recycling alternatives, namely recycling and end-of-life management, item recycle and recycling solutions (prolonged service life via simple and rapid substitute of broken parts) and recyclable pieces; consumable parts and materials throughout usage cycle.
- Improve after-life recycling involving recovery/exchange programs, second-hand sales, non-destructive dismantlement and refurbishment recycling of the item and minimizing the components used in the commodity.

Financial factors are important in the design and analysis of reuse and recycling approaches, the market price of recycling versus the price of new products. Luckily, increasing resource international market costs advantage reuse and recycling. However, we must also be interested in the effects of reuse, for example, when much better effective and eco-friendly new technologies and services become accessible, the replacement of obsolete goods might be environmentally less harmful.

7. Effects on renovation and reuse

Traditionally, safety, performance and cost were the key factors in the decision to build a product. However, globally changing business conditions force organizations to re-analyze their strategic decisions. Thus, additional factors such as raw material costs and environmental legislation are taken into account in planning and construction decisions. This leads to a shift in factors that affect reuse and refurbishment. Two key factors are the shift from the sale of the product to the sale of capacity (shifting to 'product-service' systems [37]) and the shifting of some companies away from production to the assembly or redemption of segments. As for the first, traditionally, manufacturers sell the products to their customers, so that there is a transfer of ownership from the manufacturer to the customer. Today, some manufacturers choose to retain the ownership of their product and instead sell the product's capability to the customer. One such example is the "provision with time" in the aerospace industry. The manufacturer acts as a service provider and assumes any risks associated with the failure of the product. As the consumer buys only the capacity guarantee, the interest is focused on customer satisfaction with the provided capacity, and so the product age (number of life cycles) becomes less important. Renovation and reuse reduce the costs of organizations that adopt the business model of service, for example, maintenance costs are reduced through the use of refurbished and reused components, and whole remanufactured or refurbished machines can be used instead of more expensive new ones. In the latter case, some producers, in order to reduce costs, buy components from countries with lower labor costs and simply assemble these parts. This however, leads to the loss of the required engineering skills for the reconstruction.

8. Availability of information on components, materials and methods of repairing products (including influence of scarce resources on sustainable EEE design)

There is a clear difference between the position of the original manufacturer and the independent specialist. The original manufacturer will have access to all original manufacturing information as well as subsequent mechanical changes throughout the product's production path. Most manufacturers provide a dedicated production line to keep their interest in producing new products, but some companies such as Ricoh are running re-operational products on the same lines as new products.

The required detailed info usually provided by the company would assign the opening to an associated operator who can work on-site at the location of the producer or at one's own venue. The producer could also have links to authentic products of spare parts and distributors, and perhaps provide new and existing parts to update the re-launched devices.

Autonomous repair professionals are far more constrained to restart because they work without the initial producer license. They have no links to method or item suppliers' information and therefore need to gain substantial technological capabilities in other manners. Necessary parts are bought from the open market, whether new or even used, and often specifically from licensed and autonomous service suppliers, or from the distribution channel of the supplier or its associate. In certain situations, full systems for parts acquisition should be acquired to allow components to be replaced for products to be re-operated. Product knowledge and experience may be acquired through the recruitment of staff previously employed by the original manufacturer or their authorized sales and repair partners.

Depending on the size of independent experts, resumption capabilities vary with the size and depth of the process, but even larger independent companies cannot invest in full reproduction of the original maker's production or restart environment. Repair and restoration methods will generally be similar between the manufacturer, the authorized representative or the independent specialist, to test the product, re-operate at the required level and prepare for use. Independent experts may generally have the most efficient line to bring a used product back into a repaired or refurbished mode, while the manufacturer may choose to invest more in time and cost of re-operation to provide a good quality of used product with a similar warranty.

All participants are responsible through decision-making phases, which assess the product's re-launch at different stages to guarantee an environmentally friendly degree of re-operation is selected that facilitates second-hand market at a gain rather than a loss. Many producers will not pursue the high secondary market revenue of used appliances since they are willing to give independent companies the first and most favorable deal to provide as much customer service as feasibly possible.

8.1 Selection of sustainable materials and processes

The choice of materials and processes is another important element of DFS. There are eight key criteria for these purposes: (1) consumption of resources, (2) energy consumption, (3) dangerous substances emissions, (4) origin and transport, (5) aspects of life span, (6) waste generation, (7) biodiversity and protection of natural areas, and (8) social aspects.

9. Conclusions

Currently, in the sector of recycling of waste electrical and electronic equipment, there is a growing need for rigorous and comprehensive policies to reduce the ecological effects of WEEE. Challenges and opportunities involve ecological pollution, mineral resources scarcity, waste treatment, and landfill deterioration. Thus, WEEE's regeneration and reconstruction are rather essential owing to its huge environmental consequences. Sustainability is not a stationary condition, but a system of dynamic equilibrium between the human environment and the ecosystem. Cofactors that play an influential role is sustainability strategy and environmentally friendly design techniques, dismantlement and reuse architecture, and what they indicate for home appliances. Policies and regulations as well as standards should be identified in the light of opportunities, techniques and equipment for environmentally friendly architecture of consumer electronics, with specific focus on reuse, recycling, choice of environmentally friendly new materials, and finally limited resources.

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