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Mandated prices as an instrument to mitigate environmental impacts in informal reuse/recycling

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Abstract

The management of international flows in used electronics goods and e-waste has emerged as a new environmental challenge. In addition to the mitigating environmental impacts of informal recycling in developing countries, the objectives of extending product lifespan, reducing costs of IT equipment in the developing world and employment should also be considered. It is not yet clear whether all of these of objectives can be simultaneously achieved. There can be significant tradeoffs associated with policy proposals aimed at achieving one objective over another. Application of the Basel Convention to e-waste is complicated by the fact that many environmental emissions, such as dioxins, are generated in the informal recycling process, and are not associated with toxic materials contained in the product. It is also important to note that even if toxic materials are entirely designed out of electronics, the environmental impacts generated in informal recycling processes would still be unacceptably high. Another challenge for international trade is the question of how to distinguish between reusable electronics and e-waste directly for recycling. Also, as domestic generation continues to rise, restricting imports does not address the challenge of how to safely process domestic e-waste. These factors suggest that addressing the informal sector is needed to solve the problem. This article addresses a new policy approach: to eliminate environmentally damaging processes in the informal chain through the economic instrument of fixed market prices for select parts resulting from the disassembly process. The price is set such as to create an incentive for informal recyclers to deliver parts to central collection sites rather process on their own. This would be implemented by a government program which, in addition to mandating prices, would also ensure that these collected parts are processed in appropriate recycling facilities. For example, it is possible that providing financial incentives for collecting circuit boards, wires and CRT glass may mitigate the significant environmental impacts while maintaining reuse, profitability and employment in the sector Further study is needed, however, to determine if an appropriate set of financial incentives would realize an affordable and effective system.

Keywords

e-waste, used electronics, environmental impacts, international trade, informal sector, formal sector

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1. Introduction

Informal recycling of waste electronic goods (e-waste) in developing nations is emerging as a environmental challenge for the 21st century. Informal refers to recycling conducted on a small scale, often by individuals at a household level and not officially registered as a business. Exposés by NGOs such as the Basel Action Network, the Silicon Valley Toxics Coalition and Toxics Link have revealed that such home-grown computer recycling industries in China and India are causing environmental havoc (BAN/SVTC 2002, ToxicsLink 2003). It is suspected that similar problems are on the rise elsewhere as well. In these cases, waste electronics is usually processed with the most primitive of processes. For example, wires are collected and burned in open piles to recover re-saleable copper. Circuit boards are treated in open acid baths next to rivers to extract copper and precious metals. Volumes of waste equipment needing processing are increasing rapidly in both the industrialized and industrializing worlds. Despite significant attention from the media and enactment of some national level trade bans (most notably China and India), the problem is apparently worsening.

These informal economic activities that have developed around electronics reuse and recycling is one example what is termed a “grey sector”. These tend to play a larger role in developing economies. Other grey sectors related to recycling/reuse are landfill scavenging and ship-breaking. There are also in certain cases equivalent gray versions of manufacturing, retail and service activities. The reuse/recycling related grey sectors seem to be of particular environmental concern and important for policy and other actions to mitigate impacts. As will be discussed further in this article, what responses are appropriate are not obvious. The essential dilemma posed is that the income provided by these activities to those in poverty creates a mechanism for the informal whenever conditions are right. Lack of governance and means to enforce legislation targeted at these activities remains a huge obstacle.

This article analyzes the informal reuse/recycling sector in developing countries from the perspective of what policy responses might be most effective at mitigating environmental impacts, considering the prevailing governance and economic conditions. It also addresses the issue of what objectives such policies should consider in addition to mitigating recycling impacts. Given this perspective, an alternative to existing approaches is proposed.

2. Informal reuse/recycling of IT hardware

This article focuses on reuse and recycling of IT hardware, mainly computers, though some of the discussion applies to other electrical appliances. In order to discuss solutions aimed at mitigating environmental impacts of the informal sector, it is important to first understand its technical, labor, economic and environmental characteristics. While study and analysis of the informal sector remains scarce, in this section available information on practices in China and India is overviewed (BAN/SVTC 2002, Streicher-Porte et. Al. 2005). Figure 1 shows a simplified process diagram of activities and flows within the sector. To avoid confusion with the “other PCBs” (poly-chlorinated biphenyls), circuit boards are referred to by their alternative term, Printed Wiring Boards (PWB).

Describing the overall flow, the starting point is end-of-life electronics from foreign and domestic sources. This input is a mix of machines which could potentially be reused and resold and e-waste. After resellable machines have been culled, the remainder is disassembled. Disassembly yields some resellable parts (e.g. power supplies), a set for recycled material markets (e.g. iron, plastic, aluminum parts) and other parts for additional processing (e.g., copper wires, circuit boards, CRTs). Copper is a valuable material for resale, but plastic casings must be removed. In proper recycling this is done with shredders and separation machines. In informal recycling this is often done by open burning of piled cables. Some end-of-life CRTs can be refitted with electron guns and be resold. CRTs also contain copper-rich yokes that are removed for materials recycling. Circuit boards containable valuable gold, silver and copper, which are typically recovered using acid baths. Many steps in this chain of processes have waste outputs, such as CRT glass, non-recyclable plastic parts and PWBs after metal extraction. Characteristics of each individual process are summarized in Table 1.

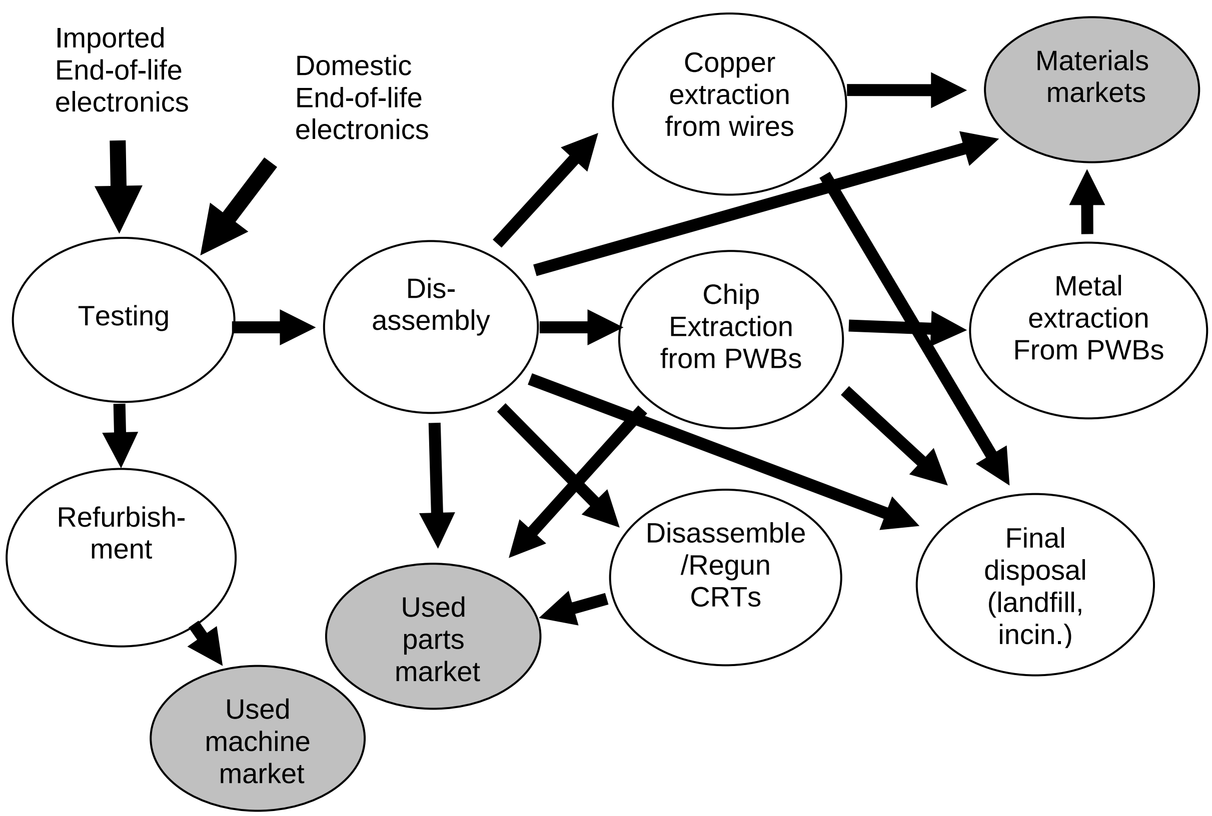

Figure 1: Process network in the informal recycling sector for IT equipment
(PWB = Printed Wiring Board, CRT = Cathode Ray Tube)

It is important to note that outputs from these processes feed three distinct markets: used computers and monitors, components and materials. Note that informal reuse/recycling generates net income, while in contrast is a net cost when done formally in rich countries. Higher labor costs and the expense of environmental controls are no doubt important in this, but it is also important to note that there is little reuse in developed world practice, so the revenue stream is also less.

Little is known regarding net income and employment generated by informal recycling. The only data available at the time of writing this article is from a study of A. Jain on the Dehli recycling system. In this study, a CRT regunning/recycling operation processing 100,000 units annually had net sales of 220 million rupees (5 million USD) and employed 470 workers full time (Jain 2004).

Process	Typical method	Inputs	Outputs	Environmental Issues
Testing	Manual inspection, test	Used & broken equipment	Reusable devices, broken devices	-
Refurbish	Manual	Equipment	Equipment for resale	-
Disassembly	Manual	Computer	CRTs, steel, plastic, aluminum, wires, populated PWBs	Worker safety
Copper extraction from PWBs	Open burning	Wires	Copper, air emissions	Emissions from burning, especially PVC coated wires (dioxins, furans)
Chip extraction from PWBs	Heat with coal stove, pulled by hand	Populated PWBs	Depopulated PWBs, chips for resale	Air and soil emissions from lead-based solders
Disassembling/ regunning CRTs	Partly mechanized	CRT	CRT for resale, copper yoke, CRT glass	Worker safety
Metal extraction from PWBs	Acid baths	Depopulated PWBs	Gold, silver, copper, waste PWB	Acid runoff, water/soil emissions of heavy metals, worker safety
Final disposal	Open dump	CRT glass, plastic casings, PWBs		Leaching, inc. heavy metals

Table 1: Characteristics of informal recycling processes

It is clear from existing analyses that the environmental impacts of informal reuse/recycling are considerable. Since the original BAN/SVTC report, a group based at Hong Kong Baptist University has been carrying out a series of scientific studies to characterize concentrations of different pollutants associated with e-waste processing in the Guiyu area in China (Leung et. Al 2004). One result of their study was that sites of open burning of cable wire showed extremely high levels of dioxins (12,419 ng TEQ/kg waste input) and furans (15,610 ng TEQ/kg) , about three orders of magnitude higher than those for the open burning of household waste. Total levels of polycyclic aromatic hydrocarbons (PAHs) in the sediment of the waste printer roller dump site were were high, with a highest value of 593 μg/kg. High levels of lead (365 mg/kg), copper (531 mg/kg) and zinc (241 mg/kg) were found in sediment and soil samples collected around the Guiyu area.

3. Environmental impacts of manufacturing IT hardware

The e-waste issue came to the global agenda in the context of the environmental impacts of the informal recycling sector. It is also important to consider life cycle environmental impacts of IT equipment and how they are affected by international flows of used equipment. The environmental impacts of manufacturing IT equipment are significant. In terms of energy, producing a typical desktop computer with monitor requires 6,400 MJ, or 260 kg of fossil fuels (Williams 2004a). This weight of fossil fuels is 12 times the weight of the computer, indicating a high energy intensity for manufacturing per weight of product. For an automobile or refrigerator, for example, the ratio of fossil fuels needed for manufacture to product weight lies between 1 and 2. The origin of this high energy intensity is primarily due to the high material and processing environment requirements for high-tech components such as semiconductors. The fossil fuels needed to produce a 32MB DRAM chip, for example is 630 times its weight (Williams 2002). Environmental impacts are not limited to energy use. Chemical use in semiconductor and PWB manufacturing is considerable, the former in particular uses a great variety of substances which are toxic and must be carefully handled (Williams 2004b).

Rapid tech cycles in the IT industry magnify its environmental impacts, as they induce consumers to purchase computers and other IT goods much more frequently than other durable goods. People often purchase five or more computers for every refrigerator. Home users in Japan, for example, buy a new computer every three years (Williams 2005). High energy intensity combined with short lifespan results in a surprisingly large degree of life cycle energy use. The yearly energy use associated owning a desktop computer (including manufacturing and operation) is 1.3 times that a refrigerator, despite that the latter is larger and consumes far more electricity during operation (Williams 2004a).

Most computers disposed of by a user are still functional. This combined with the high energy intensity of manufacturing suggests that extension of life span is a key strategy in managing the gamut of environmental impacts (energy use, chemical use, waste treatment, etc.) associated with computers. The idea is that to the extent that if extension of lifespan can mitigate unneeded manufacture of new devices, environmental impacts manufacturing could be avoided. Another way to state this is that for computers, the conventional 3R (reduce, reuse, recycle) hierarchy of waste management is tilted even more towards reduce and reuse compared to most other goods. Despite this, nearly all effort thus far in the formal sector for recovering electronics focuses on recycling materials, the environmental “payback” of which is relatively tiny.

One practical way to extend lifespan is by encouraging markets for used personal computers (PCs). In this regard, the issue of international trade in used PCs is potentially key. Given rapid declines in prices of new computers, the used computer market is facing increasingly difficult circumstances. However, it is important to note that the price gap between used and new computers, expressed in terms of purchasing power, is far larger for those in developing countries than for those in rich nations. For example, while a Japanese consumer faced with the choice between an $800 new system or a $300 used one, the $500 will likely not seem such an additional burden considering the benefits of a new system. For consumers in developing countries, however, several hundred dollars often represents several months or more of salary. There is thus a potentially large demand in the developing world used machines deemed unattractive to users in industrialized countries. However, the environmental benefits of reuse are much less clear whether it is contributes to developing new markets. However, making computers more available to users in developing countries contributes to bridging the digital divide, and thus serves a social purpose, which is the topic of the next section.

4. The development context

In addition to the environment, it is also important to consider the relationship between the reuse/recycling sector and development issues. The challenge of dealing with the trade-offs between environment and development objectives are particularly acute in industrializing nations. There are two main development issues associated with international trade in used electronics: availability of IT equipment and the contribution of reuse/recycling as a value-added economic sector.

International trade in quality used equipment represents an opportunity to bridge the digital divide by making computers more affordable. The digital divide continues to contribute to widening the gap between industrialized and industrializing. While there are many factors associated with the digital divide, the expense of IT goods and infrastructure is one important obstacle. MIT's Nicholas Negroponte has received much media attention for the "$100 Laptop" project, which aims at computer redesigned for children in developing countries which would have a pricetag of $100 (BBC 2005). While there are certainly many design changes possible to bring costs down, it is not clear that even a $200 laptop is feasible from a technical perspective. In the highly globalized and intensely competitive computer industry, new laptops costing less than $400-500 have yet to appear on the market. However, used laptops and desktops near the $100 price point are already available. There are however unresolved challenges in ensuring quality of used goods.

The other development issue relates to employment and income generated by the reuse/recycling sector. Viewed as a global industrial sector, industrializing nations have distinct competitive advantages in reuse/recycling. First, if done for recovery of reusable machines and parts, it is a labor intensive industry, so labor costs are important. Secondly, demand for the outputs of the industry, used machines parts and materials are higher in many industrializing nations. Considered separately from the environmental challenges, is the potential economic/employment contribution of a reuse/recycling sector significant? Given the dearth of information, it is difficult to make assertions with confidence. If the sales and labor characteristics for CRT disassembly/regunning reported by Jain for the Delhi industry are characteristic for the overall sector, I attempt a rough estimate of the current potential market scale for e-waste. If there are around 600 million computers in use today, it is likely that around 150 million become e-waste each year. Scaling the previous figures for Delhi, this suggests a total employment of 100,000 persons and $7.5 billion revenue for the global computer reuse/recycling industry. Needless to say, given the rapid growth of computer use in China, India and other places combined with large populations, the equipment needing reuse/recycling will grow rapidly and eventually be dominated by domestic sources. Further work is needed to refine estimates (including other equipment) to understand the degree to which the degree of economic contribution the sector could make. The main point of this section is to suggest that reuse/recycling should be analyzed as an economic sector in its own right.

5. Existing policy approaches

Given the context of the previous sections, one can argue that the management of international used electronics/e-waste should be considered as a multi-objective challenge. In line with the charter of the Solving the E-waste Problem (StEP) Initiative, an international project addressing e-waste, the objectives to consider for the international reuse/recycling chain for electronics should be considered to be (StEP 2006):

A. Mitigating environmental impacts of informal recycling

B. Increasing lifespan and reuse of IT equipment and components

C. Contributing to economic and social development through access to IT equipment and employment

Whether all three objectives can be met is not yet clear. Indeed, approaches to addressing one can conflict with realizing others. For instance, banning international trade in used electronics would contribute to achieving objective A, but limit B and C. Unrestricted trade with no other action would favor B and C, but likely increase problems with A.

In this section the existing policy approaches to the international e-waste problem are discuss in the context of the three objectives.

i) Trade controls

Controlling international trade in used electronics and e-waste is one important policy option. Nations are free to enact individual rules on what imports and exports are allowed, to the extent these do not conflict with requirements of members of the World Trade Organization (WTO). The main existing international framework for controlling trade in e-waste is the Basel Convention. The Basel Convention is an international multilateral agreement intended to address international flows in toxic wastes. It requires prior notification between signatories when trading wastes classified as hazardous. Many categories of e-waste (not intended for reuse) are classified as hazardous waste targeted for prior notification. There is also a proposed amendment to the Convention, the so-called Basel Ban, which forbids international trade in all the materials categorized by the Convention as hazardous. This amendment has not been ratified and seems unlikely to be in the near future.

A major complication in applying the Basel Convention, both in terms prior notification or an outright ban, is the exemption allowed for reuse. The definition of hazardous e-waste specifically exempts goods intended for reuse. However, there are no guidelines given how reusable goods are distinguished from non-reusable. There is clearly much background work needed on the form of such guidelines and on practical systems that could implement the guidelines.

It is important to consider whether the Basel Convention is an appropriate framework for managing the used electronics/e-waste. The Convention is, by definition, formulated around addressing trade in hazardous wastes. Used electronics/e-waste has two important qualitative distinctions which complicate its interpretation as hazardous waste. One is making the distinction between reusable equipment and waste, as discussed above. The other is the fact that environmental impacts associated with informal recycling of e-waste are only partly due to its content of toxic materials. As is clear from section 2, many of the harmful emissions, such as PAHs, dioxins and acids, are generated or used in the informal recycling process itself. A computer free from the toxic substances that cause it be classified as hazardous would still generate unacceptable environmental impacts if recycled informally.

There are different levels of trade control possible. NGOs such as BAN and SVTC call for the most strict: a unilateral ban in trade in e-waste. This proposal does not however specify how to define e-waste in practice in the context of reusable goods versus waste. There are also possibilities for certification and classification of trade. Considering that specification of flows of used goods and waste is not classified clearly in most systems for gathering trade statistics, there is clearly much progress to be made. These are also important in the economic and environmental performance of the reuse/recycling industry: management is difficult without being able to monitor and control input steams.

Trade controls imply distinct implications in terms of realizing the three objectives. First it is important to consider whether they would actually achieve their primary objective of reducing impacts due to informal recycling. One issue is the enforceability of trade rules. E-waste processing is an income generating industry, thus there is an economic incentive for the industry to develop wherever conditions are favorable. Developing and developed country governments are thus faced with challenges in enforcing trade bans. For instance, while imports of e-waste were banned in China, anecdotal reports indicate that informal recycling continues in Guiyu, though less openly. If a given nation is successful in enforcement, there is also the possibility that the flow of e-waste could be displaced to another country where conditions are more favorable. Also, while trade controls in principle restrict imports of e-waste to a given country, they do not address the question of how to manage increasing volumes of domestic e-waste.

A second issue is the relationship between trade restrictions and the second two objectives. Industrializing nations have competitive advantages in electronics recycling (lower wages, higher demand of outputs) so some might consider developing the sector through encouraging e-waste imports. How to develop a domestic recycling sector that is both profitable and environmentally acceptable is not yet clear. It is at the same time, however, a challenge that has yet to be seriously considered. The upshot of this discussion is that, at present, there exist scenarios in which trade controls on e-waste are not desirable to achieve the desired objectives.

ii) Redesigning electronics to remove toxic content

The principle of this strategy is to find alternatives to replace materials of concern in electronics. For instance, there is a variety of solder formulations that do not contain lead, such as silver-tin mixes. Certain brominated flame retardants are considered to have much higher potential for health impacts than others, thus replacing those of concern (i.e. PDBEs) with those considered safer (i.e. TBBPA) is presumably beneficial. Also, there are flame retardants which do not contain brominated compounds, such as zinc borate.

Separately from considerations of impacts of the informal sector in the developing countries, the European Commission has enacted legislation, the Restriction on Hazardous Substances (RoHS) Directive, which bans certain materials in specified electronics applications, such as lead in PWB solder (European Parliament 2003). While formulated based on considerations within European, this legislation may have beneficial effects on informal recycling in developing countries. It is probable, thus unproven, that removing lead from solder would reduce worker exposure when pulling chips from PWBs. Some argue that further efforts to remove toxics from equipment is an important strategy to address environmental impacts in the informal sector (BAN/SVTC 2003)

It is important to consider again the discussion on the origin of pollutants from the previous section in the context of product design. To reiterate, a vast portion of the toxic emissions from informal recycling are generated in the recycling process. Thus, eliminating impacts through design requires the use of materials that would not generate toxics even if processed using the most primitive of methods (i.e. open burning). There are many possibilities to reduce impacts in this context through redesign. For instance, if PVCs were eliminated from wire cabling, emissions of dioxins from open burning would clearly be less. One must recall however a major reason PVC is used because of its thermal properties. Finding materials that both deliver needed safety and technical performance as well as being safe to open burning is a massive technical challenge. Most specifications for "safety" under open burning conditions are probably impossible to meet under currently known materials and technologies. Also, precious metals would have to be eliminated from electronics in order to remove the incentive to remove using unsafe processes. It is the opinion of the author that it is impossible in the foreseeable future to design a computer safe under open burning of components and containing no precious metals.

The conclusion of the above discussion is that while changing the material content of equipment can significantly reduce environmental impacts of informal recycling, it cannot by itself solve the problem.

6. Alternative approach: mixed formal/informal sector using regulated prices

Thus work on how to safely implement electronics recycling in developing countries has received little attention. The main exception to this is the project "Knowledge Partnerships with Developing and Transition Countries in e-waste Recycling" (www.ewaste.ch), which was launched in 2003 by the Swiss Federal Laboratories for Materials Testing and Research (EMPA) and primarily supported by SECO, the Swiss economics agency. One aspect of the project involves undertaking case studies in India, China and South Africa to characterize e-waste processing practices and conditions in these areas. The conceptual basis of the project follows the “double dividend” approach, which has gained popularity in recent years. This is the idea that enhanced knowledge and management can improve environmental and economic performance simultaneously. Thus major goals are to do to identify best practices and to communicate this knowledge and train practitioners.

As in the EMPA project, this article takes up the question of how electronics recycling might be safely practiced in developing countries. The starting point is a presumption that a degree of formalization of the informal sector is required. It is not plausible, in the author’s opinion, to expect household industries adhere to environmental standards. The most direct solution is to follow the example of developed nations and implement a nationally mandated recycling system. There are two main problems with this approach. One is that the experience thus far with such systems is almost overwhelmingly with materials recycling, with little or no reuse of equipment or parts. Existing systems in developing countries are also capital intensive and lead to a net cost of recycling electronics. The other problem is that even if a national recycling system were implemented, it would not reduce the incentive for informal recycling to take place. As long as households can earn income, informal activities will continue unless a ban can be enforced.

Economic instruments are probably the most effective means to reduce informal recycling. To be precise, a government mandated price for e-waste components could provide an incentive for potential practitioners to turn in parts rather than recycle informally. Components or machines collected via this subsidy would be designated for processing by a formal recycling system with proper environmental controls. Prices are presumably fixed to be higher than what the informal recycler would earn from household processing. While it is clear that such an incentive would be effective in principle, the fundamental questions are whether the necessary level of subsidy would be affordable in practice and whether an efficient system could be set up. The simplest form of this would be fix prices for all inputs, from reusable computers to circuit boards. This essentially be a subsidy for collection of inputs to a formal recycling system. However, given the lack of experience with implementing reuse friendly systems, the level of required subsidy would probably be high.

One can also consider the possibility of permitting a mix of informal and formal recycling activities. Some informal recycling processes are clearly far more harmful than others. The steps with the highest environmental impacts are probably open burning of wire cables, acid-recovery of precious metals from PWBs, chip recovery from PWBs, and disposal of CRT glass (see Figure 1). These can be initially identified as the main environmental “hotspots” that require action (though others may be identified upon further study). One option is to fix prices only for populated PWBs, wires and waste CRT glass and designate formal recycling processes for these outputs. The idea of such a price fixing scheme is shown in Figure 2. With this system, high levels of reuse and employment would presumably be maintained while not requiring undue expenditures on subsidies. It also limits focuses attention and resources on developing formal recycling on the key areas.

The proposal to fix prices on these three items is preliminary, based on currently limited knowledge of environmental impacts of the informal sector. Also, it is not yet clear what prices would be appropriate and how requiring proper recycling of these items would affect the overall economic balance of the system. These are clearly important questions that must be addressed to proceed with this approach and are topics for future study. One key question is the source of subsidy. For imported e-waste, one possibility is a product specific tariff that would cover the additional costs associated with processing in the formal sector. Also note that such a system would require a more refined classification of the different types of used electronics/e-waste that currently exists.

The intent of this article was to set context and propose fixed prices as an economic instrument as a means to mitigate environmental impacts of informal reuse/recycling. The questions of what processes must be avoided, appropriate price points, revenue system, and appropriate options for formalized recycling steps must be investigated to determine whether this is indeed a feasible approach.

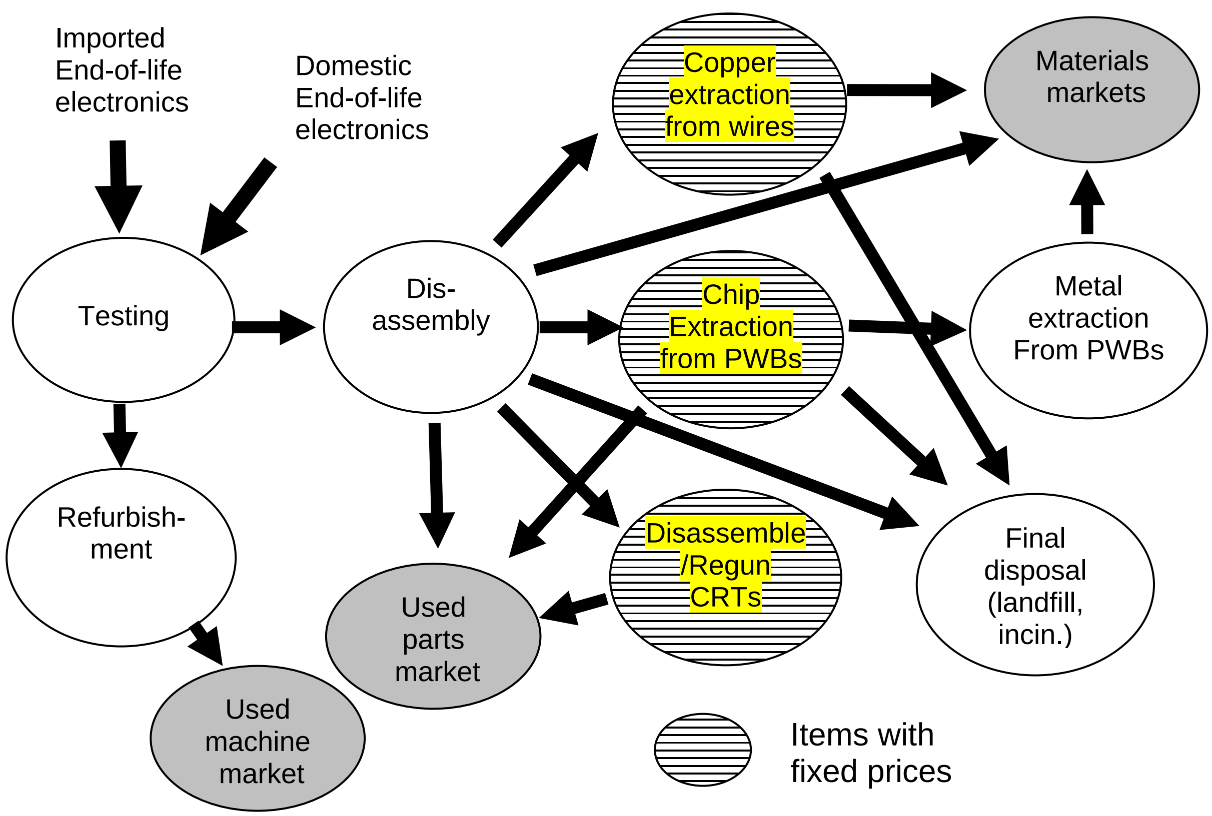

Figure 2: Reuse/recycling system with fixed prices to avoid informal processing for environmental "hotspots"

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