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REVIEW ARTICLE

Take back and treatment of discarded electronics: a scientific update

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Abstract This paper indicates that the performance of tack-back and treatment of electronic waste (e-waste) system can be improved substantially. This can be reached by better taking into account in a better way the big variety in material composition and potential toxicity of electrical and electronic products – from a technical, organizational and regulatory perspective. Realizing that there is no 'one size fit for all' and combining smart tailor made solutions with economic of sale will result in the best environmental gain/cost ratio. Several examples show how science and engineering have supported or will support this approach.

Keywords e-waste, take back, treatment, substantially

1 Introduction

The generation of electronic waste (e-waste) is becoming an increasingly critical problem throughout the world. As the volume of this waste continues to grow, its toxicity creates increasing threats to both the environment and human health [1–5]. The researches on materials flow [6,7] and their legislations [8–12] on e-waste have been attracted lots of concerns globally. Meanwhile, take back and subsequent treatment of e-waste has been now discussed for almost 20 years. In several regions of the worlds this has resulted in legislation to make this happen. In Europe, take back and treatment systems started to operate in several countries at the end of last century with all Member States of the European Union following after 2005 (basis: the EU WEEE Directive). Japan was the first country in Asia to introduce a system with R. O. Korea following soon. Singapore, Australia and Thailand are still in the stage of consideration. China has introduced its Recycling Law for e-waste in 2009; the basics are therefore in place but further implementation rules are in process. In the America, several states in the USA and Canada have introduced legislation as regards e-waste; in other states and other counties (Brazil, Mexico) legislation in under consideration.

Take back and subsequent treatment has been primarily a political issue with a strong emphasis on environmental issues. Particularly in the beginning, the scientific perspective was missing. In the financial domain, a lot of attention has been paid to the question 'who has to pay what' and 'on what basis should be paid (market share, return share and so on)' rather than addressing the reduction of the overall cost of this system. This situation has led to rule making which is delivering not enough environmental gain for the money spent. In Europe [13], environmental effectiveness the primary issue whereas in Japan cost is a primary concern [14].

Scientific work on take-back and treatment started just before the turn of the century; results took too much time to penetrate and had therefore limited effect in implementation by the first moves. By now, insights have developed even further. This gives countries which are initially still blank in implementation (like China, Australia, South Africa, Brazil and so on) the opportunity to benefit from this. Moreover, present knowledge can assist in overhauling system already in place. The recast of the WEEE Directive of the European Union is a good example in this category.

The present paper will first address a number of publications by Delft University of Technology and Tsinghua University on take-back and treatment of e-waste (Sect. 2). These reflect the current scientific insight on the subject. On basis of this, a selection of these items will be presented which are in the opinions of the authors' most relevant to come to eco-efficient take back and treatment systems today.

It should be emphasized here that the above list is a

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prioritized selection of items and by no means a comprehensive one. Moreover organizational/financial matters like paperwork (registration, proof of compliance) and financial items (who pay what on what basis and organizing competition among transport, recycling systems) have not been considered. Although there are essential to operate take back and treatment systems in an eco-efficient way, these are felt to be outside the scope of this paper.

2 Key papers of Delft and Tsinghua research on take-back and treatment of e-waste

Research work in this field started at Delft in 1996. Key papers of the work include:

• J. Huisman: The QWERTY/EE Concept, Quantifying Recyclability and Eco-efficiency for End-of-Life Treatment of Consumer Electronic Products, dissertation, June 2003. This work allows to map take-back systems and individual products in these systems from both an environmental and an economic perspective. Moreover, environmental-economic diagrams are introduced in which the effect of 'actions' (change in treatment technology, product design, system organization and even legislation) can be visualized (and prioritized).

• Ab Stevels: Adventures in Eco-Design of Electronic Products (1993–2007), published privately now available through Amazon.com. In the chapters 7–9 of this book, take-back and treatment aspects are addressed. Chapter 7 discusses historical development and technical aspect; chapter 8 focuses on system organization whereas chapter 9 addresses legislation.

• J. Huisman, R. Kuehr et al. 2008: Review of Directive 2002/96 on Waste Electrical and Electronic Equipment (WEEE). This is an environmental, economic and social impact assessment of WEEE based on an extensive data collection in the 27 EU member states. Particularly scope, collection, recycling, reuse and toxic control are considered. On basis of this analysis, proposals are being made to further improvement of WEEE (the recast).

Research at the group at the Tsinghua (School of Environmental) has a long tradition in toxic control and in treatment technologies. Through the cooperation with Delft University of Technology (starting in 2002), more product specific issues have been addressed. Key papers in this field include:

• Ab Stevels and Jinhui Li: An agenda to move forward Electronics Recycling in China. Proceeding of World Recycling Congress. Shanghai Nov., 2005. This paper 'translates' research work and experience on recycling in Europe into a Chinese setting and give recommendations how e-waste treatment in China can be started best.

• Li Ying and Ab Stevels: How China can beat Europe in Environmental Legislation for Electronics. Proceeding of World Recycling Congress. Shanghai, Nov. 2006. This paper identifies five areas in which China in its future legislation can do substantially better than Europe.

• Jinhui Li and Ab Stevels: Suggestions to optimize the Chinese Recycling Law and its implementation, internal document, Beijing, Nov., 2009. In this document, results of scientific work at Delft and Tsinghua and practical experience with systems in Europe and Japan are used to optimize the Chinese Recycling Law and its implementation. For the implementation, eco-efficiency is proposed as the guiding principle. The consequences of this for both the technical and organizational issues are considered in detail. Moreover suggestions are done for university research and the further development of the Recycling Industry in China.

The documents cited above form the basis for the recommendations to come to eco-efficient take-back and treatment systems.

3 General items

3.1 The goal of take back and treatment systems

It is realized that the goal of take back and treatment systems for discarded is twofold:

• On one hand, optimize material recycling

These goals can be (partly) conflicting; priorities in collection, recycling and treatment of secondary streams should be adapted according to the material composition. For instance for products containing high amounts of precious metals, recycling should be focused on recovering these to the very last amount (ppm level) (cell phones, DVD players), see also in Sect. 4.3.

• On the other hand, control of (potentially) toxic substances

Products containing high amounts of hazardous materials (Chlorinated fluorocarbons-CFCs in fridges, mercury in lamps and LCD back lights) should get specific targets for collection and control of such toxics. In this respect it is to be realized that the hazardous effect of CFCs (cooling fluids in fridges) is approximately 10000 times as worse as the same amount of CO_2. For lead this ratio is 2000:1, for mercury 2500:1 and for chromium 1000:1.

Contrary to what if often thought, there is no specific cost which can be attributed to 'recycling' or to 'toxic control' of e-waste. Results obtained depend strongly on the amount of money spent to achieve these goals. A certain minimum amount is required anyway; this is the cost of collecting goods and transport to processors. How much cost is to be spent on the treatments is dependent on the targets which are to be reached. Reversely, it is useful having criteria available to set meaningful targets to develop systems further and to balance requirements in different product categories. Using such criteria can also be helpful in disseminating best practices and fostering competition among recyclers.

In the key referred papers [14–16], the criteria proposed is the use of 'ecoefficiency': the ratio between environmental gain and cost. This has been worked out in detail for material recycling in Europe. Numerous ideas have been developed in this basis; whereas ecoefficiency has also been used to rank proposals for the WEEE Review [15].

The cooperation between Delft and Tsinghua will put special focus on developing similar ecoefficiency criteria for China.

3.2 Environmental aspects of products to be treated

When treating products, the environmental value of materials to be recycled varies greatly. Precious metals have a special position in this respect. Although as regards weight such metals only occur in tiny amounts in products (0–50 mg), these can dominate the complete treatment strategy. This is demonstrated in Table 1 where it is shown that recovering one milligram of gold represents the same environmental effect of recovering 1–20 g of common metals and plastics (ratios have been calculated in basis of the 'eco-indicator 99' system).

Table 1 Environmental equivalency of recovering materials (baseline is 1 mg of gold)

material	environmental equivalent for 1 mg gold
plastic	20 g
iron	8 g
aluminum	2 g
copper	1.3 g
palladium	0.3 mg
nickel	0.25 g
platinum	0.2 mg
silver	0.08 g
indium	0.05 g

It is concluded from this table that for relevant products (like cell phones, DVD players) in general products with miniaturized electronics treatment should be precious metal driven; recovering every milligram is the number one priority rather than recycling as much as possible in a weight basis (as the European WEEE requires).

This has far reaching consequences to treatment and upgrading. When discarded products are treated through shredding and separation, 100% of precious metals should be concentrated in one fraction (the copper fraction) and leakage into for instance the mixed plastic fraction should be avoided by choosing appropriate settings (or radical simply take on board all mixed plastics in the copper fraction). Also upgrading of such fractions needs special attention. It has been claimed by Hagelüken and Meskers [15] that the efficiency of precious metal recuperation can be more than 90% in specialized smelters, whereas in standard copper smelters this is only 65%–70%. In the informal recycling sector (leaching of precious metals with help of acids) the efficiency is only 25%. Like in Europe most likely the investment of a dedicated smelter in China is already profitable today–both from an environmental and an economic perspective. A societal issue will be that people in the informal recycling sector in for instance China get paid more for disassembling precious metal containing subassemblies are not exposed to health risks and do not produce hazardous waste anymore.

Such special rules should particularly apply to products in which the use of hazardous materials in exempted under RoHS (the European Directive on Restriction of Hazardous Substances). In present practice this issue is pretty much neglected; last attention is paid to maximize recycling also for these items.

3.3 Economic aspects of treatment of products

Like the environmental value of the various materials in electronics, products vary greatly as well. This is shown in the table below. This table has been composed on basis of the London Metal Exchange in Oct, 2009.

Table 2 Relative economic value of materials in electronic products (baseline is in 1 mg of gold)

material	price equivalent for 1 mg gold
iron	43 g
ABS plastic	13 g
aluminum	10 g
copper	4 g
nickel	1.3 g
silver	0.06 g
indium	0.03 g
palladium	2.5 mg
platinum	0.6 mg

This table show similar proportions as the environmental one. This is not amazing because the amount of energy used to transform minerals (raw materials) into pure ores is roughly higher the rarer the metal concerned is. On top of this short-term market fluctuations impact the ratios; In Oct., 2009, the gold price was relatively high due to instability in the financial market, whereas prices of metals like iron, aluminum and copper are relatively low due to recession.

Yields of secondary materials abate collection and treatment cost. Only in a few cases yields are so high that cost turns into an overall yield. This is only the case of the products contain a (relatively high) amount of precious metals like cell phone and DVD players. Products containing a lot of metals have a moderate net cost of treatment. Glass dominated products have generally a higher cost plastics dominated products score the worst.

Taking this into account it is obvious to organize the different types of discarded goods according to their material composition. When formulating requirements on collection, recycling and toxic control for each category the principle of the maximizing the environmental gain/cost ratio should be applied and a balance should be sought between the different categories. So far, the European Union has used categories based on application area rather than on material composition and cost likely this organization will be kept in the current Recast process. Since other countries are still blank in this respect there is an opportunity for the systems to be developed in this country to be more eco-efficient and to reduce paper work.

3.4 Scope

In view of Sect. 3.2 and 3.3, it is recommended to include in the scope (products to be treated) following products, irrespective whether they originate from consumer or industrial application: (i) Fridges/freezers; (ii) Washing machines; (iii) CRT and LCD based TVs and monitors; (iv) Computers; (v) Cell phones and related items.

In this product list, 79% on a weight basis all e-waste is being addressed and 88% of the environmental gain (and of the hazardous control) is being addressed while cost is at a minimum [15].

The EU has no product list but wants categories of products to be included and wants "o" make a distinction between commercial e-waste (B2C) and business e-waste (B2B) as well. This leads in practice to a lot of discussion about what is 'in' and what is 'out' and to what is considered to be B2C or B2B and what to do in cases of mixed B2C/B2B streams. On top of this, the category approach makes that a lot of smaller electronic items have to be addressed for which there is little environmental gain at large extra (often administrative) cost.

3.5 Flexibility in targets

Setting up and operating take-back and treatment system is a complex operation in which there is a lot of learning underway. Simultaneously external developments like increased development of environmental science, advances in treatment technology, development in the upgrading industry and last but not least changes in material price have a big impact.

Based on experiences with implementation of recycling law in the last ten years, it is recommended therefore to split take back regulation into two parts:

• A Basic Law setting the principal rule and responsibilities. Also the tasks of the different stakeholders are to be described here. There are the rules to be set for a longer period of time.

• Implementation rules. There are a flexible set of rules which can be adapted regularly. Such rules can consider: (i) Scope; (ii) Collection amounts; (iii) Recycling rates; (iv) Treatment of secondary streams resulting from the primary treatment.

Neither the EU nor Japan has implementation rules; changes have to be made by going through the complete lawmaking procedure. With its basic law now in place, China is very well positioned to set up an implementation rule system.

4 System operation

4.1 Collection

Appropriate collection of e-waste is important to the environmental success of any take back and treatment system; only if a substantial part of the discarded product is taken back and treated according to the environmental standards set by regulation, real success can be claimed.

In Europe in 2008, around 13% of the WEEE is still land filled whereas 54% is submitted to substandard treatment [15]; the balance of 33% being OK. The percentage in Japan is estimated to be 25%–30% in 2005 [14]. Volumes for substandard treatment are thought to originate chiefly through leaks in the official collection system; for instance by 'back-door' trade at shops or informal trading at municipal scrap yards. Final destination of these streams is often at third world countries. As such this is not a problem as long as it leads to reuse of the discarded products. Whether this really happens in very doubtful; informal recycling practices with goods originating from Europe have been identified in several non- EU countries.

Also in Japan a similar situation exists. Yoshida and Yoshido [14] report that of home appliances some 50% ends up in the official treatment systems. 30% is being sold for 're-use' (85% being 'reuse' overseas) whereas the balance goes to other focus of material recovery. It is concluded that 'stopping the leaks' in the official systems is a number one priority both in Europe and Japan. How this would work out and how in environmental terms is also illustrated by figure where the environmental impact of increased collection (by a factor 2) is shown for all the product categories. Increasing collection has a dramatic environmental effect, particularly in the category fridge and the freezers (second from left); this is due to the toxic control of the CFC's. Dramatic gains, both in absolute and relative terms are present in the categories. Small household appliances, IT, flat panel displays and consumer electronics containing CRTs (fourth, fifth, sixth and ninth from left). For lamps (eleventh from left) the gain in relative terms is very high, in absolute terms pretty modest (mercury control).

In China, informal reuse and recycling activities are dominating the take-back scene. A lot of material is being brought directly from consumers by peddlers and traders going from door to door [14]. Official systems will have to compete with such forms of collection by giving financial incentives directly to consumers. A demonstration that this could work is give by the observation that the economic stimulation package in which consumers get a discount when an old product is brought back when a new one is being bought is very successful.

Starting from Aug., 2009, Chinese government launched the ‘household appliance old for new trade-in’ program [17]. It has the goals to: stimulate domestic purchase of new home appliances for the economy; explore an effective model to formally take back e-waste from consumers. In this scheme, when consumer returns e-waste to the formal collection channels, one is eligible for 10% discount when purchasing a new home appliance. Subsidies for logistics, recycling and discount of new equipments are issued entirely by government. The five acceptable product types are TV, refrigerator, washing machine, air conditioner and personal computer (including laptop). Any type of old equipment for any new product is allowed. A total amount of 57609000 of large home appliances has been collected since “trade-in” policy was launched from 2009 to 2011. Among the home appliances collected, TVs, refrigerator, washing machine, air conditioner and personal computer (including laptop) are 18624000, 7552000, 6982000, 14082000 and 8473000 units, respectively. The experience from the collection program has shown that: the collection issue can be solved with a considerable amount of money/subsidy to buy e-waste from consumers, and it can divert the e-waste flow from the informal channels to the formal system [17–19].

4.2 Treatment

Generally, it can be stated that cost of treatment of discarded electronic products has been stable in the past ten years or even has become lower. This is due to (on average) increase of economy of scale at recyclers, better organization of de-production lines and increased investment in advanced equipment. This has led to is situation where the legal requirements for recycling (the recycling targets) could be met (or exceeded) in most cases. Mostly these requirements are based on weight rather than on environmental importance of the various material fractions. It can be argued therefore [13] that some of these targets are not ambitious enough in the sense that the importance of precious metals (see Sect. 3.2) and the importance of high level reapplication (see Sect. 4.3) are not sufficiently addressed.

Treatment of e-waste is in the developed world about seeking a careful balance between disassembly (high labor cost) and mechanical treatment (shredding/mechanical separation), high investment cost. The material value of most products (see Sect. 3.3) is such that in these regions of the world product with a weight below some 5 kg are not worthwhile to disassemble (under toxicity issues make it mandatory to do so).

In the third words, particularly in countries like China and India there is a third opportunity due to the low labor cost: deep disassembly. This means that disassembly takes places into much more fractions (and a products with lower too). In this way, purer fractions are obtained (less upgrading cost, better yields) and the obligation of investment in equipment for mechanical treatment is limited.

Also with respect to ‘informal recycling’ as practiced in such countries, deep disassembly has substantial advantages too. The advantages of deep dismantling with useful to its alternatives are listed in the table below.

From Table 3 it can be seen that deep disassembly offers substantial advantages from the environmental perspective (upper 3 lines). From the cost perspective the advantages are limited so far [16], but improvement is expected to take place in this department due to the fact that deep disassembly has only been carried out in a pilot scale [16]. Full industrialization will bring economic of scale and therefore cost reduction. The lowest five lines of the table show that already now deep disassembly is good for

Table 3 Positioning deep disassembly between high tech recycling and informal recycling

opportunity for	informal recycling	deep disassembly recycling	Hi-tech (shredding) recycling
components reuse	limited	yes	no
high materials yield	no	yes	moderate/high
efficient upgrading of secondary fractions	no	yes	moderate
low cost	yes	moderate	no
good eco-efficiency	no	yes	reasonable
low amount of toxic waste	no	yes	moderate
health and safety	no	yes	yes
local community	yes	yes	limited
national resources	modest	high	moderate/high

eco-efficiency, helps to reduce waste and contributes to more general sustainability goal as health and safety, local communities and national resource policies.

4.3 Upgrading and reapplication of materials

From both an environmental and an economic perspective, it is desirable that secondary streams resulting from treatment of e-waste are upgraded to their purest form. However, the purer the end product, the higher the cost of upgrading will be and the more losses in the form of waste will result. Such realities of economics and physics are well shown in ore processing, separation of chemical mixtures etc. but not always realized in the environmental world. Simply going for the highest level of purity or even ‘up-cycling’ are ideals thought to be preferably served. In practice, however, compromises have to be accepted for example:

- Having glass of cathode ray tubes in a form that it can be reused for glass production results losses of some 30% of its theoretical environmental value (waste). This is still better than to use the secondary glass as for instance road filler material.
- Mixed plastic fractions sometimes are so much a mix of types and colors that the best (eco-efficient) solution is to go is incineration.

Apart from preparedness to go for compromises between yield and quality, also the aspect that one material has to ‘sacrifice’ for a ‘lead material’ is relevant in considering upgrading processes.

- The data shown in Sect. 3.2 and 3.3 make that for cell phones all materials have to ‘sacrifice’ for the recuperation of the precious metals. It has been even argued that it is best to process complete phones in specialized precious metal smelters although the consequence is that the plastics of the phone are incinerated (only) and the recuperation of the rest of the metals in this process is not optimized [14].
- In a study an integrated Pb-Zn smelter [19], it is shown introducing Cathode Ray Tube screens of for instance monitors in their totality into this process is very advantageous from an environmental perspective. The lead oxide in the glass is transformed into pure lead, the silica and other components of it act only as a flux agent and finally end up in slag. This is better for the environment than upgrading the glass and recycling it in new glass. The only disadvantage is the limited capacity of such mixed smelters in the world.

5 Technology and design

5.1 Economy of scale

Practical experience as well as semi-empirical calculation demonstrates that take back and treatment of e-waste need economy of scale to ensure the best ecoefficiency of the operations [14]. This is caused by a multitude of factors ranging from collection (volume of stream), treatment (investment in sophisticated equipment), upgrading (technology, value of secondary streams in the market) and presence of sufficient competition between transportation companies, recyclers and system organizers.

It is estimated that some 50000 tonnes/year of WEEE are needed to have sufficient economy of scale in all operations.

Since take back and recycling in the EU are organized on the level of Member States, the ‘50000 tonnes rule’ indicates that all States will less than 10–15 million inhabitations are ecoinefficient in their WEEE implementations due to low population. This will result either in less environmental performance than would be possible (although the EU requirements can be fulfilled) or in too high prices. Also in Member States with a bigger population, ‘regionalization’ of the e-waste issues or fragmentation due to the presence of too much systems or too much recyclers (absence of real market forces) can lead to a similar sub optimization [20].

Allowing cross boundary transport of e-waste would lead to better environmental performance (development of treatment specialists for certain products or secondary fractions), better investment decisions and lower prices.

Mostly likely, Japan is ecoinefficient too, chiefly due to the high cost of take-back and treatment. The presence of two systems only, each having numerous recycling factories seems to be the chief reason for this. It has been demonstrated that achieving the appropriate economy of scale has a bigger effect on the ecoefficiency than having the latest treatment technology or than introducing product to the market with the best ‘Design for Recycling’ [13,14].

This aspect is therefore to be taken into account when introducing e-waste systems for instance in China (less developed provinces will collect not enough waste to achieve economy of scale themselves) or in Federal States where the responsibility for waste is entrusted to individual States (Australia, Canada, USA).

5.2 Measuring performance of take back and treatment systems

Performance of take back and treatment is related to the goals and targets which have been set to such systems. Therefore the ecoefficiency criteria discussed in Sect. 3.1 is a useful yardstick to measure performance P general would be as Eq.(1):

$$\mathrm{PR\ or\ TC} = \frac{\sum(\mathrm{net})\mathrm{environmental\ gain}}{\mathrm{costs}}. \quad (1)$$

PR represents Recycling Performance (R) or Toxic Control (TC) performance. The expression (net) represents environmental respectively ‘toxic’ loads involved in collection and transport as well as losses through fractions resulting from the treatment which still have to be put to landfill (or incineration). 'Gain' means that a comparison is made between two situations that is the one with the treatment and the one without.

'Environmental' means in case of recycling the environmental value of each material which is recycled. This value is dependent on the environmental load of producing the material which the recycled material is replaced. Generally such data are known [14] and particularly reference I shows example of performance calculations as outlined above. In this reference it is also demonstrated that the present performance indicator in the European WEEE, the weight based recycling percentage is a poor reflection of true environmental performance. Instead of replacing this weight base, the increasing of the amounts collected has however priority in our opinion (see also Sect. 4.1). The time till a next WEEE Recast can be used to study the performance measures issue further so that a mature PR can be introduced in a next round.

This also holds for the toxic control performance. Here the principal difficulty is that currently there are no indicators available for 'environmental gain'. Although some indicators have been proposed like the Toxic Potential Indicator (TPI), discussed by Nissen et al. [21], much more work will be needed to get PTC systems which are workable in practice.

5.3 The role of design for recycling

One of the important principles on which the early thoughts on take back and treatment were based was the principle of Individual Producer Responsibility (IPR). Idea was that if individual producers would be made for the costs of recycling, they would start to redesign their products so that costs of recycling would be reduced to zero. If done smartly this could even lead to a competitive advantage. It has been demonstrated however since that time that the far majority of electronic products have a structured recycling cost deficit [15], which can be a reduced somewhat by Design for Recycling. Moreover, other items like achieving economy of scale (see Sect. 5.1) and having appropriate treatment technologies available have been shown in practice much more important for achieving cost reduction.

In spite of this the WEEE Directive in its current form is still showing the history of the last decade of the previous century; it is still a mix of a 'Design Directive' and a real Waste Directive. It is hoped that after the Recast process it will be turned into a full waste Directive allowing on both individual as collective solutions giving priority to those which serve the goal of getting "the most of environmental gain at the lowest cost' the best.

In fact there are strong arguments in the very Eco-Design as well. For a given functionality, design for material reduction is to be preferred over design for recycling – even if the material reduction leads to a lower recyclability of the product. The reason for this is that the efficiency of recycling is mostly (far) below 100% (collection rate, treatment efficiency, reapplication level of secondary).

Nevertheless, Design for Recycling can contribute substantially rather in the form of 'Design for Disassembly'. In this way it is serving dominantly other goals like simplifying product architecture (lowering assembly cost), competitor analysis of fixture (another form of simplification). Examples of such activities are described by Stevels and Boks [22].

6 Conclusions

Due to the large variety in electrical and electronic products as regard material composition and weight and variety in industrial infrastructures to treat these products, regulation of take back and treatment product should be a flexible. It has been demonstrated however that starting from the common basis to maximize environmental gain at minimum cost, systems can be developed which fulfill the required societal function, both recycling of crucial for the success of such systems are increasing collection, recouping the environmentally most valuable materials to the full and achieving appropriate economics.

The development of systems to measure environmental and economic performance of take back and treatment systems will be essential to support further development. In regions of the world where systems are already in place there will be ample of room for improvement if principles dating form before the time of the century are replaced by sights which science and engineering have developed on the subject in the past 15 years. Simultaneously these offer to countries entering the areas of take back and treatment of e-waste to start and to leapfrog countries sticking to outdated ideas.

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