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One WEEE, many species: lessons from the European experience

Deepali Sinha Khetriwal[1], Rolf Widmer[1], Ruediger Kuehr[2] and Jaco Huisman[2]

Abstract

Electrical and electronic equipment (EEE) pervades modern lifestyles, but its quick obsolescence is resulting in huge quantities of EEE to be disposed of. This fast-growing waste stream has been recognized for its hazard potential. The European Union's (EU) Waste Electrical and Electronic Equipment (WEEE) Directive was essentially in response to the toxicity of e-waste – to ensure that it was collected and treated in an environmentally sound manner. Since then, the WEEE Directive has expanded its aims to include recovery of valuable resources as a means to reduce raw material extraction. With these objectives in mind, the Directive sets a common minimum legislative framework for all EU member states. However, the transposition of the Directive into national legislations has meant many differences in actual implementation models. There are 27 national transpositions of the Directive with different definitions, provisions and agreements. Each legislation reflects national situations, whether they are geographical considerations, legislative history, the influence of lobby groups and other national priorities. Although this diversity in legislations has meant massive problems in compliance and enforcement, it provides an opportunity to get an insight into the possible operational models of e-waste legislation. Building on the study by the United Nations University commissioned by the European Commission as part of its 2008 Review of the WEEE Directive, the paper identifies some key features of the Directive as well as legislative and operational differences in transposition and implementation in the various members states. The paper discusses the successes and challenges of the Directive and concludes with lessons learnt from the European experience.

Keywords

WEEE Directive, e-waste legislation, extended producer, responsibility, European experience, extended producer, responsibility (EPR)

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Introduction - The history of the WEEE Directive

In 1991 the European Union designated e-waste a priority waste stream and began the process of developing legislation for better e-waste management. However, it was only in January 2003 that the common Waste Electrical and Electronic Equipment (WEEE) Directive (Directive 2002/96/EC) came into force, with the actual transposition and implementation in individual member states varying. The WEEE Directive is complementary to other European legislation such as the Restriction of Hazadous Substances (RoHS) Directive (also known as the 'daughter' Directive of WEEE) and the Energy using Product (EuP) Directive. The first draft of the Waste Electrical and Electronic Equipment (WEEE) Directive, as originally conceived in 1995, essentially in response to the concerns of the toxicity of e-waste [E-waste, also consisting of quite old equipment, still contains toxic substances such as lead, mercury, cadmium, brominated and chlorinated flame retardants etc. which are now banned under the RoHS Directive.] and to ensure that it was collected and treated in an environmentally sound manner (Huisman et al., 2008). Since then, the WEEE Directive has expanded its aims, and its main stated objectives are to prevent the generation of electrical and electronic waste and to promote re-use, recycling and other forms of recovery so as to reduce the quantity of such waste to be eliminated, while also improving the environmental

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performance of economic operators involved in its treatment (van Rossem et al., 2006).

A specific legislation for WEEE in Europe was needed because existing legislation on municipal waste was considered insufficient for a number of reasons.

1. There was a rapid growth in the quantity of WEEE flowing into the municipal waste stream, and its disposal is much more expensive than regular municipal solid waste, making it a burden for municipal authorities to manage.
2. WEEE stream differs substantially from the regular municipal waste as it is a complex mixture of materials and components, some of which are very harmful, posing high risks to the environment as well as human health. In Europe, WEEE was being disposed in landfills and going to incinerators as part of municipal waste, leading to concerns about toxins leaching out into the soil, water and polluting the air.
3. Finally, WEEE contains valuable resources such as gold, silver, palladium, indium, tellurium etc and other resources such as iron, copper, aluminium, etc. that can be recycled to replace primary raw material production. Thus, a system was required to prevent the loss of valuable materials in WEEE.

Current status of the WEEE Directive

The WEEE Directive came into force on 27 January 2003, and covers a diverse scope of electrical and electronic equipment, defined broadly as any appliance that works with electricity. In total, there are 10 broad categories of electrical and electronic equipment (EEE) as mentioned in Table 1. Following the subsidiarity principle, the Directive only defines general requirements to comply with mandatory collection and recycling objectives (Savage et al., 2006). In addition, as the WEEE Directive is environmental legislation it falls under Article 175 of the European Treaty, and member states could go beyond the requirements of the WEEE Directive. The modalities of the logistics and the organization of the take-back schemes are left to the choice of member states, which had a little over 18 months to transpose to Directive into national legislation, by 13 August 2004.

The essential requirements that the Directive places on member states are listed here.

1. Ensure that producers provide for the establishment of take back and collection from consumers, at least free of charge, to maximize the separate collection of household WEEE from other forms of household waste. Towards this, a minimum 4 kg capita^{-1} annum^{-1} collection target was set.
2. Ensure WEEE is treated appropriately to protect the environment by achieving high weight-based recycling targets and that any residual WEEE is disposed of in an environmentally sound manner. (For recycling and recovery targets, refer to Table 1).
3. Provide a framework for sound financing and monitoring of the entire system.

The WEEE Directive was explicitly designed on the basis of the principle of producer responsibility. Such an approach is useful for end-of-life (EOL) management of EEE since producers have the best knowledge of the materials, both hazardous and precious, in their products and are best placed to improve the overall environmental performance of a product upstream at the design and manufacturing stage as also downstream at end-of-life (Huisman and Magalini, 2007).

The transposition and implementation of the WEEE Directive into national legislation has resulted in some criticism and complaints by many stakeholders involved, in particular producers who bear the burden of compliance.

Table 1. Current targets of the WEEE directive

	Current collection target	Current recycling and recovery targets (percentage of collected WEEE)	
WEEE category	For all EU member states	Reuse and recycling	Recovery
1. Large household appliances		75%	80%
2. Small household appliances		65%	70%
3. Information technology		65%	75%
4. Consumer equipment		65%	75%
5. Lighting equipments		50%	70%
6. Electric and electronic tools	Total collection target (across all categories) 4kg capita^{-1} from households	50%	70%
7. Toys, leisure and sports equipment		50%	70%
8. Medical devices		Not included	Not included
9. Monitoring and control instruments		50%	70%
10. Automatic dispensers		75%	80%

Practice has shown that every individual member state transposed and implemented the Directive in different ways. The result is 27 different pieces of legislation with varying definitions, obligations and agreements (Huisman et al., 2008). Not surprisingly, there are more than 150 different compliance schemes, excluding small individual service providers, making it difficult to follow the actual performance of the overall system.

The European Council has recognized the need to have harmonized national policies to ensure policy effectiveness. Ironically, during the development of the Directive, it was felt that the framework set by the Directive would make it easier for member states to develop their own approach, and the complexity and inter-linkages of the entire system were not evident. However, the varied member state policies have proved the complexity and hence illustrate the need for harmonized action.

There are several issues, such as collection requirements, treatment standards, recycling and recovery targets, financing mechanisms and information and reporting requirements etc that vary substantially between member states as they are not specifically stipulated by the Directive and therefore open for interpretation in national legislations.

The following section examines a few of the most important aspects of the WEEE Directive, and discusses the differences between member states in their legislative and operational models as well as the successes and challenges faced in the implementation.

Collection obligations (Article 5)

The WEEE Directive explicitly puts the onus of collection on the producers and distributors, requiring them to accept WEEE from household consumers, at least on a one-to-one basis when selling new products. They have the possibility to deviate from this requirement if it can be shown to the national regulators that an alternative procedure is just as convenient for consumers, therefore making it possible to adopt other channels of collection such as municipal collection points, kerbside collection, etc., as long as it remains free of charge for consumers. In addition to the physical responsibility, distributors also bear some informative responsibility regarding collection from households (Sander et al., 2007) as they are required to notify consumers of where and how they can return WEEE.

End user differentiation (Article 5, 8, 9)

The WEEE Directive makes a distinction between the 'WEEE from private households', essentially covering business to consumer (B2C) sales and 'WEEE from users other than private households', encompassing business to business (B2B) sales. This differentiation is of relevance largely for financing purposes, and is not based on environmental arguments. Although the Directive makes it incumbent on producers to finance collection and disposal of WEEE from private households 'at least free of charge', it leaves producers the choice on providing WEEE disposal to business clients for free or for a charge. While different collection and recycling costs may be valid for special equipment in the B2B domain (e.g. large photocopiers, servers, etc), there is a large and increasing number of dual-use products used by private consumers, small and large businesses alike, like printers, laptops and phones. For such products, there is no benefit from differentiating between B2B and B2C, and it only goes to make compliance more complicated. The WEEE Directive leaves it open to member states to make the distinction between B2B and B2C products and operational models of compliance schemes may or may not make the differentiation. However, this differentiation gives compliance schemes, especially in new member states, the opportunity to inflate collection rates by including WEEE from business, while on the other hand it gives producers the incentive to deflate their collection obligation by declaring dual-use products only as B2B products, and therefore not part of their collection obligation.

Temporal differentiation (Article 8, 9)

The WEEE Directive makes the distinction between historic WEEE, namely products put on market before 13 August, 2005, and new WEEE, that was offered for sale after that date. This differentiation is of most relevance to the financing of the system, since it attempts to draw a line between products that were sold before the implementation of producer responsibility legislation without any provision for their end-of-life disposal, and products sold after the producer responsibility regime was in place, with the view that henceforth producers would need to make financial arrangements to ensure that their products are collected and recycled properly at end-of-life. However, some countries, such as Switzerland (which is outside the purview of the WEEE), do not make this distinction in their legislation. A strong argument in favour if such non-discriminatory policy is that over a period of time the difference would be redundant as all equipment being disposed would be non-historical WEEE. Even in countries with the differentiation, it may be possible to have a compliance scheme operating much like a pension system where there is no distinction between new and historic WEEE, because new products pay a recycling tariff which is used to pay for old products coming in the waste stream in the present.

Treatment and Recovery Obligations (Article 6 & 7)

According to Article 6 of WEEE Directive, all appliances collected should be treated in authorized facilities according

to best available techniques in order to ensure a high level of environmental and human health protection, with the onus on member states to ensure inspections at treatment facilities. Specific treatment requirements are defined in Annex II of the WEEE Directive, with the objective of ensuring the removal of hazardous or otherwise environmentally relevant components. It however gives members states the discretion to set their own minimum quality standards for treatment, the requirements for obtaining recycling permits and national audit regimes.

Targets (Article 5, 7)

The WEEE Directive sets weight-based targets for collection as well as recycling and recovery but no targets for reuse (see Table 1 for current targets). The aim of the targets is to ensure a high level of recycling and reuse of materials and set a level of treatment that will improve the recovery of materials. Additionally, it was to encourage the development of recycling capacity as there would be an assurance of WEEE supply. The collection targets do not discriminate between products or product categories and the recycling and recovery targets do not differentiate between material types, as all targets are currently based on the physical weight of the product. However, this overlooks the fact that some products may have a lower physical weight, but higher environmental weight when looked at from an eco-efficiency perspective (Huisman et al., 2004).

System Financing (Article 8, 9)

The Directive clearly makes producers responsible for the financing of the collection, treatment and sound final disposal of WEEE from both households and non-households for new WEEE. However, the crucial difference between the two is how historical WEEE is paid for and how recycling fees are charged to household consumers.

For the financing of historical WEEE, producers may charge household consumers a visible fee, which is equivalent to actual costs. Comparatively, in the case of non-household consumers, producers may independently and individually negotiate charges and do not have to make them visible. A visible fee is seen by many producers as providing some cushion against the impact that the Directive might otherwise have. Where the visible fee is not mandatory, it tends to disappear and the cost is instead absorbed into the product price (Savage et al., 2006).

For new WEEE, producers are responsible for financing waste from their own products, but may not make the fee visible to consumers. Additionally, the Directive requires that each producer provide a financial guarantee for recycling when placing a B2C product on the market after 13 August 2005, which may take the form of participation by the producer in appropriate compliance schemes for the financing of the management of WEEE, a recycling insurance or a blocked bank account, giving producers several compliance options. This financial guarantee is essential in avoiding compliant producers financing the recycling of 'orphan' products from producers who have disappeared.

Table 2 summarizes the financing principles according to the WEEE Directive.

Compliance scheme models

Compliance schemes are organizations that take over the operational responsibility of the management of the take-back and recycling system on behalf of the producers and are also therefore often called producer responsibility organizations. They can be categorised as mainly of three types.

1. *Collective multi-sector compliance schemes*. Collective multi-sector schemes have a large membership of producers, across two or more product categories. El-Kretsen in Sweden, El-retur in Norway, SWICO in Switzerland and NVMP in the Netherlands are examples of such collective producer responsibility organizations. The advantage of collective schemes is that they deliver economies of scale by organizing the collection, transport and recycling of WEEE. However, often they are effective monopolies in their markets and have been criticized for being uncompetitive and also cross-subsiding products from one category to another.
2. *Collective single-sector compliance schemes*. Compliance schemes such as ICT~Milieu in Netherlands, SLRS in Switzerland and Lightcycle in Germany are examples of collective compliance schemes which cater to only one specific product category such as ICT (Information and Communication Technology) products in the case of ICT~Milieu or lighting in the case of SLRS and Lightcycle. They provide economies of scale at a certain level but are smaller than multi-sector compliance schemes.
3. *Individual brand-based compliance schemes*. Individual brand-based compliance schemes are favoured mainly by large companies with strong brands. Arguments put forward in favour of brand-based compliance is to provide feedbacks for better design, negotiate better prices with their recycling suppliers and also protect their brand image. Although there are several individual take-back schemes by producers (e.g. Cisco, Dell, etc), these remain largely for business consumers as there are substantial operational challenges and prohibitive costs for brand-based sorting and collection of household WEEE. The European Recycling Platform, which started as the first pan-European individual brand-based compliance

Table 2. Financing principles according to the WEEE Directive (Magalini and Huisman, 2007).

	Historical WEEE (before 13 August 2005)	New WEEE (after 13 August 2005)
B2C	Collective responsibility of producers	Individual responsibility of producers
	Visible fee allowed (till 2011, 2013)	Visible fee prohibited
	No financial guarantees required	Financial guarantees required
B2B	Individual responsibility of producers for equivalent appliances	Individual Responsibility of Producers (different agreement with customers allowed)
	Customer responsibility for non equivalent appliances	Visible fee not defined
	Visible fee not defined	No financial guarantees required
	No financial guarantees required	

scheme has, however, expanded to become a collective multi-sector compliance scheme.

National frameworks

There are two distinct operational frameworks – the single national compliance scheme model and the clearing house model (Savage et al., 2006), with some modifications such as trading waste collection and recycling notes.

A single national compliance scheme is a dominant national producer responsibility organization which takes on the responsibilities of organizing the collection, transportation and recycling of WEEE on behalf of producers. Such an approach is prevalent in countries such as Switzerland, the Netherlands, Belgium and Sweden with the longest established WEEE management systems, even predating the WEEE Directive, as it is the simplest structure to implement. While the legal status of the compliance schemes differs from country to country, they are generally non-governmental, not-for-profit organizations which are set up by the trade associations of the producers.

In the clearing house model, all producers must register with normally a government-managed clearing house and report their products put on market. The clearing house determines the collection obligation of each producer based on their market share and assigns the collection and financing responsibility to the producer directly or as part of a compliance scheme. In a modification of the clearing house model, producers or their compliance schemes can make private arrangements for WEEE collection, which is then balanced at the end of the year with their required WEEE obligation on a market for tradable WEEE collection notes. Such a framework is intended to make the system more market-based as compared to monopoly compliance schemes, and also to avoid a situation in which compliance schemes 'cherry-pick' the easiest collection, leaving the less easily accessible WEEE uncollected. However, the clearing house also adds to the operational costs and complexity. Several member states, especially bigger countries such as UK, Germany, France and Spain use the clearing house approach.

Separate collection

Separate collection in the member states is achieved using one or a combination of channels. Magalini (2007) classifies them into two categories, namely active channels, and passive channels. Active channels are where the users bring back their WEEE to a municipal site, designated collection point, or to a retailer for take back, either when purchasing a new appliance or even without.

Passive collection modes are when municipalities offer door-to-door kerb-side collection, or producers and retailers provide a pick-up service (either free or at cost), or when third parties do door-to-door collection on behalf of producers or independently. The WEEE Directive does not prescribe any particular operational model for collection and therefore national transpositions and operations of compliance schemes in different countries have different channels for collection. Even within a country, different compliance schemes can use different modes of collection, and more often than not compliance schemes use a combination of collection channels.

Fee structures

The WEEE Directive does not stipulate any fee structure for recycling fees; therefore compliance schemes have the option of developing their own fee structures. There are several methods by which compliance schemes calculate and charge recycling fees – based on the basis of individual product type, price per weight, based on categories including a range of products or even as a percentage or based on product prices. Some compliance schemes use a 'fixed fee model' (e.g. SWICO Switzerland) in which they charge a fixed fee per product placed on market, whereas others (e.g. ICT~Milieu, Netherlands) use a 'debiting model' in which actual costs are calculated per time period and divided among members on a current market share basis (Savage et al., 2006). There is a trade-off between a simpler fee structure, resulting in a higher level of cross-subsidization between products with recycling fees bearing little relationship to the

actual recycling cost of the product. On the flip side, increasing product bands and fee classification increases the administrative and monitoring requirements for both producers and compliance schemes.

The WEEE review

As part of a multi-study review of the WEEE Directive, the United National University (UNU)-led consortium analysed the environmental, economic and social impacts of the implementation of the WEEE Directive in the EU27. The comprehensive study, finalized in August 2007, reported on the status of the implementation and options to improve environmental effectiveness, cost efficiency and simplification of the legal framework. This work is based on more than 183 interviews, a large database with over 350 literature items, an eco-efficiency model containing the 64 most relevant substances, 15 different environmental impact indicators, the 31 most relevant recycling, recovery and final waste disposal processes and costs for 17 WEEE subcategories (UNU, 2007).

Overall, the general consensus is that the implementation of the WEEE Directive in the EU has brought about significant improvement in the management of e-waste, and provided the impetus for the development of systems and technologies. In this section, some of the success and challenges are evaluated.

Collection challenges

Some countries have achieved separate collection rates much above the required 4 kg capita^{-1}, whereas others struggle to collect even a fraction. This disparity is understandable as there is a large difference in the amount of new EEE put on market – ranging from 24 kg inhabitant^{-1} to 6 kg inhabitant^{-1}. Overall collection percentages were observed to be roughly 25% for medium-sized appliances to 40% for larger appliances, with best collection performances in individual categories of nearly 75% for large and 60% for medium- and small-sized appliances. In most countries, small appliances pose the biggest challenge, with collection rates of almost 0%, indicating much room for improvement in collection performance. Interestingly, and inexplicably, data shows that countries with similar overall collection amounts can differ substantially in collection performance per sub-category.

Magalini (2007) identifies two key factors driving separate collection: firstly, the awareness of final users and their disposal behaviour, and secondly the availability of collection infrastructure and acceptance criteria. In the case of unspecified obligations regarding separate collection, collection points at retailers and municipalities have been seen to be demanding disproportional compensation for use of collection space and their services, especially where the national legislation does not obligate them to provide collection facilities. Retailers are charging producers and compliance schemes extra for provided services and are sometimes making a profit on collection and thus earning twice: receiving part of fees paid as compliance cost and simultaneously selling waste to brokers. The opposite also occurs, with some collection points refusing to collect WEEE. Furthermore, there is still a lack of awareness among staff at retail outlets regarding WEEE take back and disposal, especially in countries with recently implemented systems.

Another factor hindering collection is that compliance schemes in some countries were also found to be constructed as empty shells: registered, but aiming at none or bare minimum collection efforts or only cherry picking the most valuable products such as washing machines and personal computers. However, with the increase in raw material prices over the years, there has been an increasing trade of high value WEEE through non-official and often illegal channels, going from the EU27 towards emerging and developing economies especially in West Africa and Asia.

Administrative challenges

The different approaches of different member states result in inefficiencies because every producer must declare different kinds and sets of data in different countries, as no standard reporting format or criteria exists. The potential number of reporting activities across all EU member states sums up to at least 72 reports to be delivered every year per producer (UNU, 2007). A survey of all stakeholders for the WEEE Review showed that producers faced the most administrative challenges, but also considered a little additional reporting and administration a necessary evil in order to track and deter free-riders. However, the main administrative challenges that can be overcome were due to the following factors.

1. Legal aspects connected to registration (how, where, which details to be submitted to whom).
2. Insufficient clarity on definition and allocation of responsibility of producers, distributors and retailers as well as the scope of the products within and outside of national legislations, especially regarding the split between B2B and B2C products.
3. Frequency and nature of reporting including type of equipment (units, weight, level of detail)
4. Lack of consistency across member states.

Competitive equity to main stakeholders

In the consultation with stakeholders for the WEEE Review, 'free riders' were identified as a significant problem. Although it is difficult to quantify the problem, free-riding is a concern as it places an unfair burden on compliant

companies not only in terms of additional recycling costs, but also making them uncompetitive on product pricing. The review found that the problem of free-riders may be more of an issue in some countries than in others. Apart from non registered producers, another source of competition distortion is estimated to be the deliberate reporting of B2C as B2B, empty reporting without further action, or simply not reporting the full quantity of goods put on market. Surprisingly, in the consultation, 'orphan' products, namely products by manufacturers who have ceased to exist were not considered a competitive threat to existing producers.

The strengthening of market surveillance systems would address the issue of free-riders and would have a positive impact on the principle of producer responsibility by ensuring that all obligated producers placing EEE on the market are registered and fulfill their obligations (Bogaert et al., 2008).

Treatment challenges

The WEEE review found very little information on the total treatment capacity in the member states, but estimated that there is sufficient installed capacity to treat the current WEEE stream. It estimated that members of the European Electronics Recyclers Association (EERA) increased their recycling capacities from 1.2 million tonnes of WEEE annually in 2005 to 1.5 million tonnes in 2006.

However, while the WEEE Directive has resulted in the setting up of recycling capacity all over Europe, and driven innovation in improving recycling and recovery technologies, there still remain treatment challenges. Processors are not always complying with environmental rules, and are causing illegal exports by selling untreated streams to brokers. Given the limited data availability on amounts of WEEE treated through official WEEE channels, it is clear that significant portions of WEEE treatment are currently unreported, and raise suspicions of illegal exports. These exports are often to non-OECD countries in contravention of the Basel Convention and Basel Ban [The Basel Convention Ban amendment, commonly known as the Basel Ban, was introduced in 1994 to place an immediate ban on export of hazardous wastes from OECD to non-OECD countries intended for disposal, see http://www.basel.int/pub/baselban.html] Tracking and tracing containers of such illegal waste cargos continues to be a major challenge for recyclers and regulators.

Also, due to different standards for quality of treatment in different countries, not only has it created some confusion regarding treatment and recovery criteria to meet targets, but has also meant an absence of a level playing field for treatment and recycling costs. The confusion arises largely due to differences in definition of recycling, which in some member states includes reuse and both material and energy recovery, while in others recycling rates are calculated as a proportion of materials not going to landfill or incineration.

Key lessons from the European experience

Based on the results of the UNU WEEE Review (UNU, 2007), as well as other studies by Huisman and Magalini (2007), van Rossem et al. (2007) and Bogaert et al.(2008), some key lessons for effective e-waste legislation from the European experience are listed below.

1. *Providing a framework*. E-waste legislation is not only designed to reduce the hazards from the toxicity, but more so to provide a framework for the collection and recycling of WEEE. The implementation of the WEEE Directive in member states spurred the formation of infrastructure and organizations providing collection, recycling and compliance services. This is also equally applicable to countries with existing informal collection and recycling networks, as the legalization of the collection and recycling supply chain would create channels for the proper end-of-life disposal, taking out the hazardous recycling processes from the informal sector thereby reducing the toxins emitted to the environment.
2. *Flexibility to adapt to a fast changing market-scape*. E-waste legislation needs to be flexible to take into account dynamic developments such as changing products (e.g. shoes with embedded electronics) as well as changing product categories (e.g. overlapping product applications in information technology as well as consumer electronics), while also being composed of different materials requiring different treatments. The market for electronic and electrical products is highly competitive and innovative, and a legislation that has rigid product lists and compliance requirements creates bureaucratic delays, additional administrative burden, and confusion regarding compliance as new products are introduced.
3. *Applying differentiated targets*. Any e-waste legislation needs to emphasize the use of best available technology, to keep pace with changing treatment technologies, markets and options for secondary materials. Meaningful collection, recycling and recovery targets can be a useful way to increase collection and to drive innovation in recycling and recovery technology, especially if targets are based on overall eco-efficiency rather than simply physical weight (Huisman, 2008).
4. *Applying meaningful categorisation and differentiation*. Different sub sectors have different environmental costs and economic models through the entire product life cycle, with different take-back and recycling costs at the end of life. A treatment category-oriented scope is more useful than the current product-oriented scope. For example, end-of-life cathode ray tube monitors and television sets undergo the same treatment processes, but are categorized as IT (category 3) and consumer electronics (category 4), respectively. This way, a more meaningful differentiation in target setting can be developed, aimed

Table 3. Proposed categorization according to treatment requirements and revised targets for collection, recycling and treatment differentiated according to appliance category

Revised category	Collection target	Recycling/ recovery target	Treatment requirement
Large household appliances	Not required	Not required	Not required
Cooling and freezing appliances	Category-specific target required	Perhaps required	Required for removal of CFCs
Small household appliances, IT equipment, consumer electronics, tools and toys	Category-specific target required	Required, specially for plastic recycling	Required specially for removal of NiCd
Cathode ray tube-containing devices	Category-specific target required	Required specially for CRT glass	Required for removal of leaded glass and coatings
Flat panel displays	Category-specific target required	Perhaps required	Required for removal of mercury
Gas discharge lamps	Category-specific target required	Perhaps required	Required for removal of mercury

at reaching environmental goals, keeping in mind the eco-efficiency of similar products and treatment processes. Table 3 show suggestions by the UNU for a revised categorization, and identifies categories and processes to set targets for. Similarly, the artificial differentiation between products for private household and non-household consumers is unnecessary as dual-use products have the same material composition and require the same treatment on disposal, and the cost of disposal is ultimately borne by the final consumer, one way or the other.

5. *Balancing competition*. Competition in WEEE management and compliance can bring both advantages and disadvantages. Legislation should encourage competition that brings improvement in collection and treatment standards. However, the European experience shows that competition can be too much of a good thing, especially when competitive cost pressures incentivizes compliance schemes and recyclers to collect and treat at the minimum standard required. Thus, legislation should include mechanisms for ensuring balanced competition based on environmental performance rather than financial performance.
6. *Enabling awareness and enforcement*. The legislation should identify the organization(s) or stakeholders responsible for dissemination of information among both consumers and producers. Alongside, it should also provide sufficient clarity on the penalties for non-compliance, and provide for structures to ensure enforcement.
7. *Ensuring low burden of administration*. Legislation should be simple and cost effective to implement for the producers as well as regulators so as to keep the burden of administration as low as possible by taking into account existing infrastructure, cultural norms and consumer behaviour (Savage et al., 2006). Ideally, the basic legal framework with key responsibilities should be separate from the operational standards.
8. *Facilitating international harmonization*. By aligning e-waste and related legislations regionally and internationally (e.g. Basel Convention, RoHS, etc.) it may be possible to achieve easier operability for producers, create economies of scale for recyclers and provide maximum comparability to regulators.

Conclusion

The WEEE Directive is the most comprehensive implementation of a specific e-waste legislation and its development over the last decade has provided legislators, regulators and other stakeholders with a means of learning from experience. As the experience has shown, there is clearly no single best solution or legislation for WEEE which is suitable for all – whether it is in the stakeholder dimension, product dimension or geographic dimension. Moreover, it also shows that while the basic elements of the e-waste problem are similar, there are several ways of tackling it, in order to reach the same final objective of efficient and effective management of end-of-life products. However, it also shows the need to establish common standards and harmonization of national and international legislation.

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References

Bogaert S, Van Acoleyen M, Van Tomme I, De Smet L, Fleet D and Salado R (2008) *Study on RoHS and WEEE Directives N° 30-CE-0095296/00-09 Final report*. European Commission: DG Enterprise and Industry, Brussels, Belgium.

Huisman J and Magalini F (2007) Where are WEEE now? Lessons from WEEE: will EPR work for the US?, In: *Proceedings of the International Symposium on Electronics and the Environment*, Conference Record, May 2007, Orlando, USA.

Huisman J, Stevels A and Stobbe I (2004) Eco-efficiency considerations on the end-of-life of consumer electronics products. *IEEE Transactions on Electronics Packaging Manufacturing* 27(1): 9–25.

Huisman J, Magalini F, Kuehr R and Maurer C (2008) Lessons from the 2008 WEEE Review Research Studies, In: *Proceedings of the Electronics Goes Green 2008*, September 2008, Conference Record, Berlin, Germany.

Magalini F (2007) Driving Factors in WEEE Management System Design. PhD thesis: Politecnico Di Milano, Milan.

Magalini F and Huisman J (2007) Management of WEEE & cost models across the EU: could the EPR principle lead US to a better Environmental Policy?, In: *Proceedings of the 2007 IEEE International Symposium on Electronics & the Environment*, May 2007, Conference Record, Orlando Florida.

Sander K, Schilling S, Tojo N, van Rossem C, Vernon J, George C (2007) The Producer Responsibility Principle of the WEEE Directive. Study N° 07010401/2006/449269/MAR/G4 Final Report. European Commission: DG Environment, Brussels, Belgium.

Savage M, Ogilvie S, Slezak J, Artim E, Lindblom J and Delgado L (2006) *Implementation of Waste Electric and Electronic Equipment Directive in EU 25*, Technical Report. Commissioned by the European Commission: Directorate-General Joint Research Centre, Institute for Prospective Technological Studies, Seville, Spain.

United Nations University (2007) *2008 Review of Directive 2002/96 on Waste Electrical and Electronic Equipment (WEEE)*. Final Report, Bonn, Germany.

van Rossem, Chris, Nako Tojo, and Thomas Lindhqvist (2006), Lost in Transposition? A study of the implementation of individual producer responsibility in the WEEE directive. Retrieved from http://www.greenpeace.org/eu-unit/en/Publications/2009-and-earlier/lost-in-transposition/ (accessed September 2006).