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REGULATORY AND VOLUNTARY DRIVERS FOR ENVIRONMENTAL IMPROVEMENT: HAZARDOUS SUBSTANCES, LIFE-CYCLE DESIGN, AND END OF LIFE

John Hawley (Palm)

1.1 INTRODUCTION

The market for environmentally friendly electronic products is growing rapidly. Growing just as rapidly is the responsibility companies are assuming or are being compelled to assume for products through their entire life cycle and aftermath, including end of life, product recycling, and product take-back. Energy efficiency of electronic products has also become increasingly important because of their profusion and the associated load they impose on national electrical grids.

In the past the electronics industry did not consider the environmental effects of its products through their life cycles. Its primary concerns centered on how manufacturing processes or facilities infrastructure might impact the immediate environment. It also considered hazardous substances used in manufacturing processes that could have detrimental effects in the event of human contact or exposure. One example of the former consideration was the transition to volatile organic compound–free (VOC-free) processes. Freon, a type of chlorofluorocarbon (CFC), for instance, was used to clean electronics, even though it was known to be a highly ozone-depleting chemical. The electronics industry responded by developing "water-clean" or "no-clean" processes that eliminated the need for CFCs. The challenge now facing the industry is to ensure that product design, manufacture, and end-of-life activities are equally environmentally sound.

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This chapter examines some of the regulatory trends and voluntary efforts that are transforming the electronics industry worldwide in the drive to design more environmentally friendly products.

1.2 SUBSTANCES OF ENVIRONMENTAL CONCERN

For the last ten years there has been a concentrated effort to address the problem of potentially hazardous substances found in electronics products. Many parties have been involved, including governments, electronics producers, universities, and nongovernmental organizations. Providing impetus to the effort are environmental and public health issues. There are concerns, for instance, about improper disposal of electronic waste containing potentially hazardous substances. In some third world countries low-temperature burning of electronic parts in open pits for metal recovery has had seriously deleterious effects on both the health of the workers and their environment [1]. In developed, as well as developing, countries, leaching of heavy metals such as cadmium, hexavalent chromium, lead, and mercury from landfills containing electronics into the groundwater has created public health concerns. One well-known example is a case involving hexavalent chromium. An electric utility in California had used hexavalent chromium to mitigate corrosion in a cooling tower in the town of Hinkley between 1952 and 1966. The wastewater slowly dissolved the hexavalent chromium and discharged it into unlined ponds. Some of this material leached into the groundwater and eventually entered the town's drinking water. Over time the contamination resulted in serious health problems [2]. Another well-known case is that of Minamata, Japan, where a chemical company dumped mercury compounds directly into the bay between 1932 and 1968. Three thousand people developed very serious health issues and many died [3]. A third example is in Silicon Valley, where the US EPA (Environmental Protection Agency) Superfund sites were required to clean up groundwater contamination from chemicals linked to birth defects, such as trichloroethane and Freon, from certain semiconductor processing facilities [4].

One outcome of toxic substance release into the environment has been the modification of criteria used to judge risk. In the European Union, a leader in the effort to eliminate substances of environmental concern, the "precautionary principle" has been relied on for assessing risk. The precautionary principle advises caution in advance of effect: if an action or policy seems like it may cause severe or irreversible harm to the public or to the environment, and if there is no scientific consensus that harm would not ensue, the burden of proof falls on those who would adopt the action or policy. The principle implies that there is a responsibility to intervene, to protect the public from exposure to harm where scientific investigation has discovered a plausible risk.

1.2.1 Hazardous Substances Legislation: EU-RoHS

The European Union's Restriction of Hazardous Substances (RoHS) Directive (2002/95/EC)[5] became effective on July 1, 2006. This legislation has served as a model for the rest of the world where restrictions are placed on certain hazardous substances in

TABLE 1.1 Categories of electrical and electronic equipment currently within RoHS

Category 1. Large household appliances	Category 5. Lighting equipment
Category 2. Small household appliances	Category 6. Electrical and electronic tools
Category 3. IT/telecommunications	Category 7. Toys, leisure, and sports
Category 4. Consumer equipment	Category 10. Automatic dispensers

TABLE 1.2 Restricted substances and maximum concentration values

Restricted Substance	Maximum Concentration Value
Cadmium and its compounds	0.01% by weight (100 ppm)
Hexavalent chromium and its compounds	0.1% by weight (1000 ppm)
Lead and its compounds	0.1% by weight (1000 ppm)
Mercury and its compounds	0.1% by weight (1000 ppm)
Polybrominated biphenyls (PBB)	0.1% by weight (1000 ppm)
Polybrominated diphenyl ethers (PBDE)	0.1% by weight (1000 ppm)

electronic products. The scope of the RoHS Directive currently consists of eight of the ten categories found in the Waste Electrical and Electronic Equipment (WEEE) Directive as shown in Table 1.1. The two categories that are currently excluded from the EU RoHS Directive are Category 8 (medical devices) and Category 9 (monitoring and control equipment).

The legislation restricts the use of four heavy metals and two classes of brominated flame retardants and sets the maximum allowed concentration values (MCV) for each, as shown in Table 1.2. Maximum concentration values are defined to be at the homogeneous material level. A homogeneous material is defined as a material that cannot be mechanically disjointed into separate materials.

The Directive includes an exemption regime governed by a Technical Adaptation Committee (TAC) for certain specific applications where no viable technical alternatives exist. There are currently in excess of thirty technical exemptions that have been approved or are in the process of being approved. One exemption for Deca BDE was recently removed by the European Court of Justice on procedural grounds. The TAC is continuing to evaluate exemptions.

The RoHS Directive is evolving and is currently under general review. It appears likely that currently excluded categories 8 (medical devices) and 9 (monitoring and control equipment) will be put into scope by January 1, 2014; that in vitro medical devices will be phased in by January 1, 2016; and that industrial monitoring and control equipment will be phased in from January 1, 2017.

As part of a comprehensive review of exemptions, an external consultant to the EU Commission, the Öko Institute, has recommended that seven current exemptions be phased out [6]. The Institute further recommends limiting the scope of many current exemptions and setting expiration dates. Some of the proposed changes affecting the industry in the near term include the following:

TABLE 1.3 Possible hazardous substances to be added to RoHS

Name	Application
Hexabromocyclododecane (HBCDD)	Flame retardant
Bis(2-ethylhexyl) phthalate (DEHP)	Plasticizer typically used in PVC
Butylbenzylphthalate (BBP)	Plasticizer typically used in PVC
Dibutylphthalate (DBP)	Plasticizer typically used in PVC

- Reduction of mercury levels in fluorescent lamps, effective upon publication of the new Annex (Exemptions 1–4).
- Elimination of the Exemption for cadmium in plating, effective upon publication of the new Annex (Exemption 8). Other uses of cadmium will be exempt at later dates.
- Elimination of the exemption for lead oxide in glass used for bonding front and rear substrates of flat fluorescent lamps in liquid crystal displays (LCDs), effective upon publication of the new Annex (Exemption 20).
- Elimination of the exemption for lead as an impurity in rare earth iron garnet (RIG) Faraday rotators used for fiber optic communication systems, effective upon publication of the new Annex (Exemption 22). Expiration of this exemption on December 31, 2009, has recently been published in the *Official Journal of the European Union*.
- Elimination of the exemption for lead used in C-press compliant pin connector systems (Exemption 11). The recommended date for elimination of this exemption is June 30, 2010. The use of lead in other compliant pin connector systems remains exempt until a later date.

The European Commission and other European authorities are considering the recommendations of the Öko Institute, and the newly published Annex is anticipated shortly.

The expected changes in exemptions multiple times over the next several years will present challenges. The definition of being RoHS compliant for a product will be somewhat in a state of flux. There will be supply chain management challenges for the industry and enforcement challenges for EU member states. Large OEMs are currently working through methods of tracking and enforcing continued compliance by their suppliers, as suppliers work to address relevant changes to materials restrictions for their products.

Under the updated directive, RoHS becomes part of the European conformity mark, CE mark; new rules will be developed for exemption assessments; and at least four other chemicals will probably be added to the hazardous substances index, as shown in Table 1.3. The maximum concentration values will likely be 1000 ppm or 0.1% by weight.

1.2.2 Chemical Substances Legislation: EU-REACH

The terms of REACH (Registration, Evaluation, Authorization, and Restriction of Chemical Substances), Regulation EC 1907/2006 [7], a revised chemical substance

regulation for the European Union, began to be implemented on June 1, 2007. It has had, and will continue to have, an enormous effect on the chemical substance and preparation industry and therefore on the electronics industry. It supersedes earlier chemical directives such as 67/548/EEC [8] and 76/769/EEC [9].

Most chemical substances will eventually be subject to registration (usage > 1 ton/year/importer/producer) under REACH, and certain substances of very high concern (SVHC) will be subject to authorization or restriction. A simplified pre-registration period for over 100,000 substances started on June 1, 2008, and concluded on December 1, 2008. A new agency, the European Chemicals Agency (ECHA), which is based in Helsinki, is charged with managing REACH. Registration is required for all substances or preparations not pre-registered with ECHA, before they can enter the market.

ECHA published an initial list of fifteen candidates for SVHC status in the summer of 2008, and it is expected to make regular biannual additions to the list starting in late 2009. A second SVHC candidate list was published in August 2009. SVHCs are defined as having at least one of the following characteristics:

1. CMR: carcinogenic, mutagenic, or toxic for reproduction
2. PBT: persistent, bioaccumulative, toxic
3. vPvB: very persistent and very bioaccumulative
4. Identified on a case-by-case basis from scientific evidence as causing probable serious effects to human health or the environment, such as endocrine disruptors

A "first candidate" list is shown in Table 1.4. Only selected candidates from this list will become SVHCs.

For the electronics industry the three phthalates (BBP, DBP, and DEHP), HBCDD, SCCP, and diarsenic trioxide are probably the most significant. Under REACH the extent of obligations for article producers (e.g., for OEM companies in electronics) is less onerous than that for chemical producers, since substance and preparations manufacturers are assigned most of the responsibility for registration. Article producers ordinarily do not have to register substances present in articles; however, article producers will need to take notice of the following:

1. Assessments must be conducted to determine whether products containing SVHCs are in quantities and concentrations requiring action. If both conditions (in excess of one ton per year per importer and present in concentrations greater than 0.1% weight by weight) are met, ECHA is to be notified by December 1, 2011.
2. The supply chain is to be queried to ensure that all components of it understand REACH and are making appropriate preparations for pre-registering. All substances and preparations in use today must be pre-registered. This simplifies the registration process, since the information required for pre-registration is fairly minimal and allows producers of substances a longer timeline to complete all required documentation. The complete documentation requires a complete dossier with accompanying extensive test data.

TABLE 1.4 First candidate list for SVHC

Substance	Reason for Selection	Possible Uses
Anthracene	PBT	Used in production of anthraquinone dyes, pigments, insecticides, wood preservatives, and coating materials
4,4′-Diaminodiphenylmethane (MDA)	CMR	Rubber preservative; also used in curing epoxy resins and neoprene
Dibutyl phthalate (DBP)	CMR	Plasticizer in adhesives, pigment
Cobalt dichloride	CMR	Desiccant indicator
Diarsenic pentaoxide	CMR	Hardener for lead, copper, or gold
Diarsenic trioxide	CMR	Preparation of elemental arsenic, arsenic alloys, and GaAs semiconductors
Sodium dichromate, dihydrate	CMR	Chromate passivation
5-Tert-Butyl-2,4.6-trinitro-m-xylene (musk xylene)	vPvB	Fragrance compositions; e.g., cleaning fluids
Bis (2-ethylhexyl) phthalate (DEHP)	CMR	Plasticizer in flexible PVC and polymers
Hexabromocyclododecane (HBCDD) and all major diasteroisomers: alpha-and beta-and gamma-hexabromocyclododecane	PBT	Brominated flame retardant, common in ABS
Alkanes, C10–13, chloro (short-chained chlorinated paraffins, SCCP)	PBT	PVC plasticizer, flame retardant
Bis(tributyltin) oxide (TBTO)	PBT	Biocide, wood, paper preservative
Lead hydrogen arsenate	CMR	Wood preservative
Triethyl arsenate	CMR	Biocide, wood, paper preservative
Benzyl butyl phthalate (BBP)	CMR	Plasticizer in adhesives, paints, sealants, inks

3. The REACH Regulation requires article producers to notify suppliers and consumers of SVHC in their articles/product if the concentration weight by weight exceeds 0.1% of the entire article. Thus the basis for measuring SVHCs in REACH is quite different from RoHS, which is based at the homogeneous level. Upon consumer request, the article producer will need to supply information concerning any SVHC above 0.1% within forty-five days of receipt.

1.2.3 Hazardous Substances Legislation: China-RoHS

The People's Republic of China adopted a phased approach to implementation in China-RoHS. The first phase went into effect on March 1, 2007. The product scope is wider than in EU-RoHS and is referred to as Electronic Information Products (EIP).

The restricted substances and maximum concentration values are the same as those governed under EU-RoHS.

The first phase focused on product labeling and disclosure of hazardous substance information, but not on hazardous substance compliance. The requirements included labels including environmental protection use period (number of years prior to a hazardous substance leaching into the environment) and a table indicating the restricted substances if present.

The second phase is focused on developing specific product catalogs and premarket entry testing. If a product has been put on a key catalog, that product will have to be pretested prior to entry into the Chinese market, and it will have to meet the maximum concentration values for the six hazardous substances. The second phase was delayed several times, but the first proposed product catalog was released in October 2009. The first products to be included are mobile phones, telephones, and printers connected to computers. Exemptions based on the EU technical exemptions were also proposed. The details of the testing requirement have not been fully defined. The initial implementation of the second phase is not expected until early 2011.

1.2.4 Hazardous Substances Legislation: Korea-RoHS

On April 2, 2007, the National Assembly of the Republic of Korea (South Korea) adopted the Act for Resource Recycling of Electrical and Electronic Equipment [10], an EU-type RoHS with additional elements, similar to the EU End-of-Life Vehicle (ELV) and Waste Electrical and Electronic Equipment (WEEE). The Act came into force on January 1, 2008.

The restricted substances and maximum concentration values for electronic products are the same as those stipulated in EU-RoHS and, for vehicles, the same as those stipulated in ELV (four heavy metals). Like EU-RoHS but unlike China-RoHS, Korea-RoHS does not include labeling requirements. The WEEE portion emphasizes improvements in products to facilitate recycling, as well as establishing collection and recycling programs that are the responsibility of manufacturers using an extended producer responsibility (EPR) model. In addition the reporting requirement for manufacturers is quite complex and must be submitted in Korean.

The proliferation of materials restriction legislation continues at an unabated pace. Some recent legislation has passed in Turkey and Ukraine. Proposals for RoHS-like materials restriction legislation are ongoing in other major countries such as Brazil, Canada, and India.

1.2.5 Hazardous Substances Legislation: United States

The United States currently has no product-level environmental legislation similar to RoHS or WEEE (Section 1.4.1) at the federal level. One recent piece of federal legislation, the Consumer Product Safety Improvement Act (CPSIA) of 2008, will regulate lead and phthalates in children's products, including electronic products designed for children under twelve years of age. The program will be managed by the US Consumer Product Safety Commission (CPSC) and is comprehensive: within the scope of the

legislation are maximum concentration values, certificates of conformity, and labeling and testing requirements. Recently consideration of Resolution 2420, Environmental Design of Electrical Equipment Act (EDEE), began in the US House of Representatives. This legislation mirrors EU-RoHS but its enactment is still in doubt.

California currently has the only RoHS-like legislation in the United States. It has a narrower scope than EU-RoHS and restricts the four heavy metals (cadmium, hexavalent chromium, lead, and mercury) for electronics having a display screen greater than four inches on the diagonal. In 2008 California passed framework legislation collectively referred to as the California Green Chemistry Initiative. This legislation aims to develop a strong foundation for a comprehensive chemicals policy in the state. The legislation will identify chemicals of concern to human health or the environment, and the California Department of Toxic Substances Control (DTSC) has been granted the authority to regulate hazardous chemicals in consumer products. This is the most comprehensive state-level initiative on eliminating hazardous substances from products.

Other states have passed restricted substances legislation that has typically been very narrow in scope. Mercury legislation, for example, has passed in a number of states, including Arizona, Louisiana, Michigan, Texas, and Vermont. Certain types of brominated flame retardants, such as pentaBDE and octaBDE, have been restricted in Hawaii, Maine, Missouri, and Oregon, and an entire class (PBDE) has been restricted in Washington State.

1.2.6 Hazardous Substances: Material Declarations

As both regulatory and voluntary drivers continue to increase the number of restricted substances, managing material composition will increase in importance. The Electronic Industries Alliance (EIA), the JEDEC Solid State Technology Association, and the Japan Green Procurement Survey Standardization Initiative (JGPSSI) jointly developed the Joint Industry Guide (JIG) Material Composition Declaration. The guide is divided into JIG levels A and B. Level A materials and substances are subject to current legislation that:

1. prohibits their use;
2. restricts their use; or
3. requires reporting or results in other regulatory effects.

Level B materials and substances are those that the industry has determined relevant for disclosure because of one or more of the following criteria:

1. of significant environmental, health, or safety interest;
2. will trigger hazardous waste management requirements;
3. could have a negative impact on end-of-life management.

The Joint Industry Guide has been extensively revised and a new version recently released [11].

Other material declarations include the IPC 1752 standard, which covers RoHS, JIG, and other restricted substances [12].

1.2.7 Hazardous Substances: Voluntary Initiatives

The electronics industry, in particular the consumer electronics sector, has recently focused on the voluntary elimination of certain halogens from their products, with priority given to two common halogens, bromine (Br) and chlorine (Cl). The reasons are various and equally weighted: pressure from nongovernmental organizations (NGOs), anticipated future legislation, and the ability to control standards.

The typical definition of halogen-free is less than 0.09wt% (weight percent) Cl (900 ppm) and less than 0.09wt% Br (900 ppm) [13,14,15]. In addition the IEC and IPC standards refer to a combined maximum Cl and Br content of 0.15wt% (1500 ppm) [14,15].

Some NGOs play an important role in driving voluntary environmental initiatives, particularly in the consumer electronics space. One example of an environmentally based product rating program promoted by NGOs is the Electronic Product Environmental Assessment Tool (EPEAT), which has incorporated criteria including hazardous substance elimination, recycling, and energy efficiency for environmentally preferable purchasing [16]. Another example is Greenpeace, which has developed an environmental scorecard that includes energy efficiency criteria for rating consumer electronics companies [17]. A current focus area among some companies is the voluntary effort to eliminate antimony and beryllium and their compounds.

1.3 DESIGN FOR ENVIRONMENT/ENERGY EFFICIENCY

More and more electronics companies are employing design-for-environment methodologies to address product environmental attributes in the design phase. This approach can be significantly more proactive than simply meeting compliance requirements. Elements of design for environment can include materials selection (removal of hazardous substances), recyclability, and energy efficiency. Recyclability, for example, should consider factors such as material identification to facilitate re-use, maximizing the use of recycled material in place of virgin material, and designing to ensure that materials are easily separated. Detailed analysis of the entire product life cycle is also performed using a life-cycle assessment (LCA).

The Energy using Products (EuP) Directive (2005/32/EC) [18] of the European Union is framework legislation focused on eco-design. The objective of this Directive is to influence design in order to reduce energy use. The specific requirements for particular products are determined by separate implementing measures.

Energy consumption for the purposes of electricity production and transportation is a major cause of air pollution. Coal-, gas-, and oil-fired power plants emit greenhouse gases as well as gases that contribute to smog and acid rain. Energy efficiency addresses many objectives, including environmental benefits, cost savings, and energy security. Both voluntary and mandatory programs are in place in several jurisdictions, including the United States, the European Union, and Australia.

1.3.1 Energy Efficiency: United States Legislation

The Energy Independence and Security Act (EISA) of 2007 is comprehensive and broad in scope. A section of this legislation deals with energy efficiency for electronic products. It sets efficiency standards for external power supplies (EPS) and preempts the California Energy Commission's Appliance Efficiency Regulations. The values it sets for EPS efficiency are identical to California's Tier II EPS Standard. It also authorizes the US Federal Trade Commission (FTC) to promulgate energy use labeling requirements for certain products such as televisions, computers, and set-top TV boxes.

1.3.2 Energy Efficiency: United States Voluntary Program

The US Environmental Protection Agency's (EPA) Energy Star is a voluntary energy efficiency program that has been successful with manufacturers and consumers alike. The program is run in coordination with the US Department of Energy (DOE) and private stakeholders. It covers more than thirty-five product categories, including office equipment, consumer electronics, home appliances, lighting, and heating and cooling equipment. The objective of the program is to improve energy efficiency in a product, minimizing any deleterious environmental impact, without sacrificing features or performance. Products must meet strict energy performance criteria set by the US EPA or US DOE to be eligible for Energy Star certification and associated labeling. The program evolves constantly, with more rigorous specifications released on a timely basis. The Energy Star program is widely respected in the European Union, where some of its standards have been, or will be, adopted. The energy efficiency proposals under the Energy using Products Directive have been strongly influenced by the Energy Star Program.

1.3.3 Energy Efficiency: Australia Legislation

Australia has established Minimum Energy Performance Standards (MEPS). Products that are covered by MEPS include refrigerators, clothes washers and dryers, and dishwashers. New MEPS programs starting in November of 2008 now cover products such as external power supplies, set-top TV boxes, and home audio and video equipment. Australia's MEPS have also been adopted and implemented in New Zealand.

1.4 RECYCLING AND TAKE-BACK

Proper recycling of electronic products has become increasingly important, for a number of reasons: concern about illegal transfer of waste electronic goods to third world countries for improper disposal and metal recovery, the huge burden on municipalities charged with waste management, and a growing trend to have manufacturers assigned responsibility for end-of-life management of their products.

TABLE 1.5 EU-WEEE Directive categories: Annex 1A

Category 1. Large household appliances	Category 6. Electrical and electronic tools
Category 2. Small household appliances	Category 7. Toys, leisure, and sports
Category 3. IT/telecommunications	Category 8. Medical devices
Category 4. Consumer equipment	Category 9. Monitoring and control equipment
Category 5. Lighting equipment	Category 10. Automatic dispensers

1.4.1 Recycling Legislation: EU-WEEE

The Waste Electrical and Electronic Equipment Directive (2002/96/EC) [19] of the European Union was one of the first types of legislation to prohibit dumping electronic products in municipal landfill and mandate separate recycling of these products. Annex 1A of the legislation outlines the general categories as shown in Table 1.5, and Annex 1B provides the specific products covered within the scope of the WEEE Directive.

The Directive's aim has been to ensure the proper treatment of e-waste, and to encourage recycling and reuse. It also directs the cost of recycling to producers in member states by assessing fees based on weight of product shipped into an EU member state. The producer is thereby held accountable for end-of-life recycling. This concept is known as extended producer responsibility (EPR). In addition the Directive's Annex II enumerates materials or components that must be removed prior to recycling to ensure against any contamination to the bulk of the material to be recycled. Four years after implementation, however, only about one-third of WEEE is being properly treated, while two-thirds are being diverted to other countries or landfill. The WEEE Directive is being revised to set higher, binding targets for the collection of electrical and electronic equipment. The proposed revisions include:

1. New binding targets for the collection of electrical and electronic equipment. Member states in which the consumption of electrical and electronic equipment is widespread will be assigned more ambitious targets; member states with smaller markets will be given less ambitious targets. The targets will equal 65% of the average weight of electrical and electronic equipment placed on the market over the two previous years in each member state.
2. Recycling and recovery targets that include the reuse of whole appliances.
3. Weight-based targets to increase by 5%.
4. Targets for the recovery of medical devices.
5. Producers' registration and reporting requirements will be harmonized and national registers will be made inter-operable.

1.4.2 Recycling Legislation: United States

Recycling and take-back legislation in the United States currently is at the state rather than the federal level. The scope of covered electrical and electronic products varies somewhat from state to state. Typically covered products include video display

products (televisions, monitors of dimensions four inches (10 cm) or more diagonally), computers (both desktop and laptop), general consumer electronics, and batteries.

A brief comparison of Washington State's and California's financial models for recycling and take-back programs provides a good example. California's financing scheme is called advance recovery fee (ARF). In this model consumers pay a point-of-sale fee for covered products. In the Washington model, which is the EPR (extended producer responsibility) model, the entire financial burden of recycling covered goods is borne by the producers. Under this model, producers have a tangible incentive to make recycling as efficient as possible.

More than twenty states and one city (New York) have already enacted recycling and take-back legislation. More states have legislation pending. The trend in this legislation is to place responsibility for product recycling on the producer rather than the consumer or the government (EPR model). Coordination of the directives across the states would benefit both producers and consumers.

1.4.3 Recycling Legislation: China

China-WEEE is officially known as the Regulation for the Management of the Disposal of Waste Electrical and Electronic Products. It has been developing slowly and has suffered a number of delays. When released, the regulation will be a national baseline laying out the responsibilities of various agencies. The initial catalog of products to be covered by the legislation will consist of large household goods:

1. Televisions
2. Refrigerators
3. Washing machines (including dryers) with capacities up to 13 kg
4. Air conditioners
5. Computers (desktop and laptop)

Manufacturers will be expected to pay a fee to the WEEE Management Fund, achieve recycling ratios, and maintain records.

1.4.4 Other Legislation: EU Packaging and Batteries

The EU has updated separate directives on batteries and packaging. The new Battery Directive (2006/66/EC) [20] came into force in September 2008. Both primary and secondary (rechargeable) batteries are covered. The Directive provides for establishing a WEEE-like recycling scheme, a hazardous substance section providing maximum concentration values for certain heavy metals, and ensuring ease of access to batteries in devices. The new Packaging Directive (2004/12/EC) [21] amends an earlier Packaging Directive (94/62/EC) [22]. Some of the particulars in the directives include setting up increasingly aggressive targets for energy recovery of packaging, recycling of packaging, and the reduction of heavy metals (cadmium, hexavalent chromium, lead, and mercury) in packaging. The defined maximum concentration value is 100 ppm for all four metals combined.

1.5 SUMMARY

Product-based environmental initiatives will likely accelerate and increase in scope. Due diligence must be performed by the appropriate departments within companies to ensure compliance. Proactive efforts using design-for-environment and life-cycle assessment techniques will generate eco-friendly products that will succeed in the market place, allowing environmental concerns to be mitigated by increasingly green features that are inherent and integral to the products' purpose and manufacture.

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