Title

Manufacturing industry challenges and responses to EU, California, and other product-targeted environmental regulations

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Manufacturing industry challenges and responses to EU, California, and other product-targeted environmental regulations

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Introduction

Manufacturers worldwide find themselves dealing with a brand new strain of regulation targeting the environmental performance of their products. While able to (often barely) comply with these regulations, they are experiencing extraordinary difficulties doing it in an efficient and effective manner so costs are extremely high and the results are not nearly as dramatic as hoped for by the regulators. A key challenge is that, having never before dealt with these sorts of issues, the intellectual and informational framework necessary to support it is nonexistent. Universities, standards organizations, industries, and governments – even those doing the regulating – do not have as complete an understanding of the true requirements and impacts of this new regulatory paradigm. This paper will describe the regulations, how they target products, how governments, manufacturers, and standards organizations have approached these issues and why, the problems with these approaches, and ultimately propose that the solution to the problem may lie in concerted communication between the stakeholders. To this end, the paper proposes the creation and funding of a global public/private partnership focused on pre-competitive identification of industry needs, mechanisms to ensure industry has a better understanding of the context of environmental regulations, and all stakeholders have the ability to cross-fertilize and develop approaches to common solutions.

A Short History of Environmental Regulation: Chemicals vs. Products

Manufacturing industry's purpose is to take raw materials from the planet, combine that with human intelligence and creativity, and produce items of utility and value. Since the dawn of the industrial revolution, these two classes of attributes, utility (functionality) and value (cost on the selling side and price on the buying side), have driven industry. Environment was pretty much ignored as though it were free, as though the planet could absorb whatever industry used or wasted without impact. As it became increasingly obvious that this was not true, industry's use of natural resources began to come under regulation. In the US, major federal environmental actions in the 1970s and 1980s like the Clean Air Act[i] and the Clean Water Act[ii] created or expanded fundamental national regulations requiring industry to reduce pollution of shared resources. Chemicals used in commerce were also regulated, first in the US in 1976 via the Toxic Substance Control Act[iii], and elsewhere by generally similar regulations. These regulations can be classified as primarily "operational" and "end of pipe", affecting how industry deals with manufacturing and other types of waste streams.

Many other countries adopted these regulatory approaches, resulting in the US being the de facto leader in environmental regulation of the day. The impact was that industry, as it devised technologies and standards to identify subject chemicals and emissions in order to meet these regulatory limits, compartmentalized environmental regulation around chemicals used in and resulting from manufacturing processes and keeping them out of the environment. Some of the standards and mechanisms of communication used included Chemical Abstracts Service numbers (or CAS numbers)[iv], which are unique identifiers for specific molecules, and Material Safety Data Sheets[v], which describe (often by CAS number) the hazardous chemicals contained, and how to handle them to reduce exposure and other dangers.

Since the early 1990s or so, a new type of environmental regulation has emerged that is focused more on the actual product being manufactured, than simply its effluent. From the European Union's packaging directive[vi], which was first promulgated in 1994 and targeted minimizing as well as ensuring the recyclable and non-toxic

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content of the packaging of products (which tends to have a very short lifecycle and end up in the municipal waste stream), to AB 1109, the California Lighting Efficiency and Toxics Reduction Act[vii] which defines efficiency requirements for indoor and outdoor lighting and restricts the use of certain hazardous substances in the lights, which was passed in late 2007, a swarm of regulations that began in Europe and have been modified and adopted in countries and locales around the world have attempted, whether by design or result, to place controls on how companies define, design, and produce all manner of products. How companies define and manage their "product lifecycle process" has now come under government scrutiny and industry is just starting to understand that the basic concepts long used in that process must be reviewed and modified.

Product-Targeted Environmental Regulations (PTER)

The European Union promulgated the End-of-Life Vehicles Directive (2000/53/EC[viii]) in 2000, the first in what would become a series of regulations signaling an attempt at a more holistic form of environmental regulation of products than had previously been tried in the EU and elsewhere around the world. ELV addressed not only the substances that went in to the vehicles, but also required manufacturers to be responsible for the recycling of materials once the vehicle had reached the end of its useful life. This had little direct impact on most US auto manufacturers; they all have subsidiaries or divisions in Europe that would deal with the impact. But it required two activities they had never done before: understand where specific materials were used in their products and take responsibility for a product many years after it had left the showroom floor.

In the early part of this decade the electronics industry convened with the US Environmental Protection Agency to develop a voluntary national approach to e-waste, which was called "NATIONAL ELECTRONICS PRODUCT STEWARDSHIP INITIATIVE", or NEPSI. But it would ultimately amount to nothing due to a split between a couple heavyweights in electronics that wanted full producer responsibility (also called "Extended Producer Responsibility", or EPR, it helped that they had their own recycling infrastructures) and everyone else, who preferred the Advance Recovery Fee (ARF) method, where consumers are charged a recycling fee upon purchase. Ultimately this split prevented industry associations from being able to provide guidance for a national e-waste regulation, as well. The result: state-by-state implementations of electronic waste regulations are sweeping through legislatures across the country. The opportunity to harmonize at a federal level was lost.

With the "Restriction on the use of certain hazardous substances in electrical and electronic products" directive (2002/95/EC, "RoHS") and "Waste electrical and electronic equipment" directive (2002/96/EC, "WEEE"[ix]) the EU expanded its scope of control to a broad range of technological products. By this time, the EU had garnered the attention of California, which, lacking oversight from a national electronic waste ("e-waste") regulation like WEEE, decided to take matters in to its own hands and began work on a state substance restriction and e-waste regulation that would take its cues from RoHS and WEEE. While industry lobbying resulted in a narrow scope and no post-consumer responsibility for the products[x], it broke ground in 2003 by being the first regulation of its kind in the United States. California has since passed other laws that incorporate, by direct reference, the European Union RoHS directive.

Ultimately, these regulations caught much industry in the US, as well as just about everywhere else, off-guard. Historically, environmental properties of chemicals and substances used by industry to build product was never made available, and was rarely if ever asked for, so was never taken in to account in the product development process. Technical properties such as function or mechanical/electrical/optical/thermal characteristics along with business considerations such as availability and cost have been the primary selection determinants. Europe had found a true "blind spot" to regulate industry on, and it has challenged manufacturers worldwide.

This paper will describe how and why Product-Targeted Environmental Regulations (PTER) came, to a great extent, as a "surprise" to manufacturing industries, how industry reacted to them, and the paradigm shift manufacturing industries must go through to ensure that products can and do improve their "environmental performance".

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The Product Lifecycle Process

In order to understand why there was any problem at all to begin with, we will describe how products come to be in the first place. Most manufacturing companies, particularly those beyond the "start-up" stage, follow a relatively (to extremely) formal and orderly process for developing and manufacturing products called the "product lifecycle process". Often a "phase gate" process is defined and used within a manufacturing company, whereby a number of predefined and agreed-upon deliverables and achievements are required before the product team is able to move from one phase to the next. There are several phases in the typical product lifecycle, as illustrated below in figure 1.

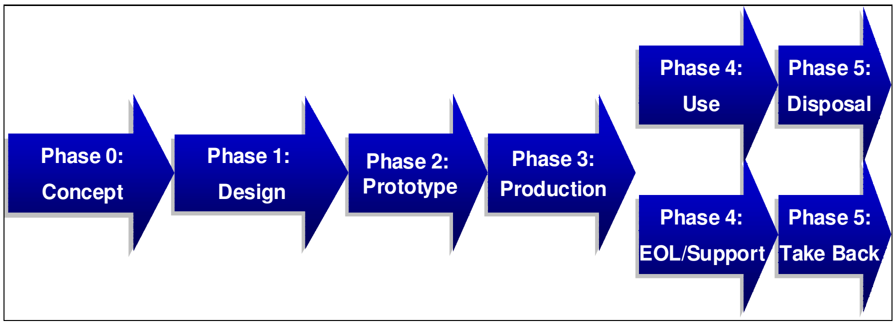

Figure 1: Example of a typical (simplified) phased product lifecycle in the electronics industry

The phases can be generally described as follows:

- Phase 0 – Concept: Market opportunities and requirements are coalesced in to a general specification for a product.
- Phase 1 – Design: Engineering determines how the product will be realized; at the same time, manufacturing and operations personnel work with Engineering to ensure the realized product can in fact be manufactured and supported as necessary.
- Phase 2 – Prototype: To this stage, engineering's work has been primarily virtual; now a functional physical example of the final product is produced to validate the design, identify and resolve any manufacturing issues or complications, and confirm that it is what was defined in the concept phase.
- Phase 3 – Production: Responsibility for the product is now transferred from Engineering to Manufacturing; the product enters in to volume production. Engineering moves on to development of the next new product while Manufacturing builds and services the product, normally feeding back any "lessons learned" to Engineering to drive continuous improvement.

Phases 4 and 5 have parallel paths. One (bottom) is for the product line, and the other (top) is for the specific piece of equipment or item. They break out as follows:

- Phase 4 – EOL/Support: Products that can last beyond their manufacturing life (for instance, a particular automobile model may be only produced for one year, but it must be supported for 10 years; computers, likewise, may be produced for 3 months, but must be supported for 3-5 years) enter in to a support period where replacement or repair parts may need to occasionally be procured or produced, particularly for products covered under service or warranty contracts.
- Phase 4 – Use: This is the consumer's use of the specific product and is normally entirely the responsibility of the final purchaser of the product or its user.
- Phase 5 – Take Back: In an increasing number of locales, manufacturers must ensure that their product does not enter the normal municipal waste stream. This is a consideration that, in fact, must be addressed during phase 0 or 1.
- Phase 5 – Disposal: As in Take Back, above, the user in many locales is not allowed to dispose of the piece of equipment in the municipal waste stream after it has served its purpose. They must be able to

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return the product to the manufacturer, or to a recycler instead. The manufacturer/producer must ensure that they can figure out how and where to do this.

The point in the lifecycle to really pay attention to for our purposes is Phase 0: the Concept phase. Manufactured products of all kinds typically begin their existence as an idea. A market is perceived and a product defined to meet the requirements of the market. Historically, market requirements have been defined along several lines:

- Functionality – what must the product do, how must it do it? This incorporates safety considerations, as well.
- Appearance or Sensory Value – what must it look and feel like?
- Profitability – What can we charge for it? How inexpensively can we make it? What's our resulting profit expectations?
- Quality and Reliability – how close to customer expectations can we make this product and how long will it continue to meet them?

Environmental performance, defined as a measure of impact on the environment (i.e. energy use, substance types and amounts, and waste during manufacturing as well as recyclability/reuse at the end of the product's useful life) of a product or item, has historically not been a requirement at this stage or, if it has, it's more related to function and cost than actual environmental impact.

Here are three examples:

1. Energy use is a primary concern for portable electronics because it impacts battery life, not because of the impact on global warming. This is a practical, direct concern of the users of these products and these are how products are sold. Notebook computers specify "Estimated Battery Life", not "CO_2 generation/hour"[xi].

2. For electronic data center products like servers and networking devices, energy use is a concern because of energy costs, cooling costs, and reliability impacts[xii], not global warming.

3. Lead, along with tin, has been used to solder electronic components together because its material, thermal, and – as a part of the solder system between parts – reliability properties have been extensively studied and documented, and are therefore very well-understood. Possible issues such as environmental disruption due to mining, toxicity to humans and the environment, and so on have never been a factor in part because lead is plentiful and inexpensive, and lead solder is never physically available to humans or the environment under normal use conditions. While it's been known for thousands of years that lead is toxic to humans, the users of tin/lead solder simply assume that the supply chain has learned how to handle it after decades of assembling electrical and electronic products to eliminate the risk of exposure. Within industry this is considered an adequate approach – when problems arise the suppliers are expected to bring them to the attention of their customers and work towards a solution. The volumes of electronic waste product, colloquially known as "e-waste", did not rise to levels of alarm until only this century, and now the concern goes beyond simply handling lead during manufacturing. We are seeing it extending to the potential increase in lead and other toxic substances used in electronic products in landfills and whether there are dangers of these substances leeching in to water tables. Additionally, questions regarding whether reuse of the extensive amounts of refined metals and plastics is a better goal than landfilling it, as well as illegal recycling in countries such as China, Ghana, and India where pollution from uncontrolled recycling is having devastating effects on local ecosystems[xiii] are becoming increasingly prevalent.

Therefore, in order to become a factor in how products are designed and built, environmental properties and consideration that can exist in any part of the product lifecycle must be identified in the concept stage of the product lifecycle process if they are to be appropriately and economically addressed in later stages. If they are

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not, and it turns out they need to be, any of a number of things can occur based on the product's specific circumstances. For example,

- If the product is at a lifecycle stage prior to volume production, changes will be defined and agreed upon, and the product release to manufacturing will be delayed. This increases costs due to having to "re-engineer" something that has already been "engineered".
- Changes required after a product is in production will result in either an early end-of-life for the product, reduction in markets (it will be taken off the market requiring the change), or engineering resources will need to be identified, a budget approved, and the product design reworked and put through a mini-lifecycle process as a revision to incorporate the needed change.
- The product will be terminated if the identified costs do not justify continued development or production

Table 1: EU Regulations vs. Lifecycle Phase impacted

	Concept	Design	Prototype	Production	Use	End-of-Life
RoHS		X		X		
WEEE	X	X				X
ELV	X	X				X
EuP	X	X		X	X	
REACH		X		X	X	X

Table 1 shows which classes of PTERs must be reviewed and addressed by phase of the product lifecycle.

RoHS: The Restriction on the use of certain Hazardous Substances in electrical and electronic equipment, or RoHS, restricts the use of certain substances in many classes of electrical and electronic products. The issue is often simply whether the engineer can find the part or technology needed in a RoHS compliant form. In the 2 years since RoHS has gone in to effect the supply chain has pretty much achieved RoHS compliance so it is increasingly difficult to design an electronic product that is *not* comprised of primarily RoHS compliant parts. Since there are always many solutions to an electronic design challenge, if the first potential solution is not available in RoHS compliant form, almost invariably another solution is that also does not compromise product goals. In fact, discussions with EU member state (MS) enforcement authorities[xiv] confirm that there have been no RoHS-related prosecutions and no convictions simply because all products that have needed to become compliant have pretty much done so, save the occasional non-compliant part that may have inadvertently slipped through.

On the other hand, this was in many cases a significant design and manufacturing challenge for the manufacturers of components and technologies used by the product manufacturers. Any change in recipe has to be vetted through a series of functional, quality, and reliability tests as well as meet the business issues of appropriate cost, profitability, and availability. In addition, as mentioned above the removal of lead from solder results in a substantial change in many manufacturing rules and requirements. These must be understood and addressed during the product design and prototype phases.

Implicit in selecting parts and technologies is the selection of the supplier(s) for those parts and technologies. In a world where vertical integration has disappeared and seemingly every piece of "value added" is embodied in its own corporation in the supply chain, vetting this disaggregated supply network for its ability to manage the changeover challenged even the largest and most sophisticated electronics companies. For instance, IBM's second quarter 2006 SEC filing stated:

> We were unable to ship to meet all of the customer demand which impacted our server brands, most notably Systems i and x. Our unusually high level of unfilled orders were due to end-to-end supply chain complexities which were primarily driven by parts and product transitions to support the RoHS (Removal of Hazardous Materials) [sic] requirement in Europe. This limited our manufacturing and sourcing flexibility.[xv]

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Note that the electronics industry's approach to compliance with RoHS was to simply replace parts to eliminate the substances where possible (and obtain exemptions where it was not). Where this was not possible very localized redesign efforts were undertaken or products discontinued in the European Union. There was no further action or impetus to go "beyond RoHS", and few (primarily driven by agendas of NGOs like Greenpeace[xvi]) have.

WEEE: The Waste Electrical and Electronic Equipment directive requires Electronics "producers" to extend responsibility for their products to the end of the useful life and provide for the cost and capability of recycling the products. They must register as a Producer with the government, identify and work with a recycler, and point their customers to them at the products' end of useful life. WEEE also proposes that products be designed for easier recycling or reuse, but not adamantly enough so that manufacturers actually pay attention. The vast majority of electronics manufacturers we surveyed recentlyxx made no design changes related to WEEE so, while it should in theory impact that Concept and Design stages, it's primarily impacting release to manufacturing ("do we have the appropriate recycling infrastructure set up and have we registered in our target markets?") and administration ("make sure we track, report, and pay whatever we need to when we need to and where we need to"). As the higher recycling percentage rates kick in we may see this change.

ELV: The End of Life Vehicles directive[xvii] requires automobile manufacturers to both eliminate certain heavy metals and flame retardants (essentially the same as RoHS, but with different exemptions) as well as put in place a recycling infrastructure to ensure that vehicles are in fact recycled. It includes target percentages that rise as time goes on, as does WEEE, to drive manufacturers to identify and use more recyclable materials.

EuP: The Energy-using Products directive[xviii] attempts to identify energy use throughout the entire product lifecycle, then use that as a consumer metric so the market can help drive improved energy performance of products. The law requires "implementing measures" to be developed and put in to place before it actually will have any regulatory effect; at this time there are none proposed, but some in the works.

REACH: The Registration, Evaluation, Authorization, and Restriction of Chemicals regulation[xix] went in to effect on June 1, 2007. It is not really "product-targeted", but encompasses products (termed "articles") with its broad scope of the vast majority of chemical substances and preparations (mixtures) used in commerce, as well as all the uses of those chemicals. The intent is to drive chemical manufacturers to produce safe use and toxicity data on substances that have been grandfathered by existing chemical policy, and therefore in use for a long time. It's impact is very broad across the product lifecycle since the selection and availability of substances can impact how a product is designed, what it is designed with, how it's used (particularly based on covered use scenarios for the chemical substances incorporated in to the article), and how it's disposed of – which also must be taken in to account in the safe use and toxicity assessments.

Industry's response to all these regulations has generally (but with notable exceptions) been to do the absolute minimum necessary in the most expedient manner possible to comply. Industry is still challenged to view environmental performance with the same holistic perspective as they do technical and business performance. The result is compliance, of course, but no more and ultimately at a very high cost. In a recent study for the Consumer Electronics Association, the consulting and market research firm Technology Forecasters, supported by DCA, determined that the cost of compliance to the EU's RoHS directive was $32.7B across the entire electronics supply chain, or about 1.1% of total annual industry revenue[xx]. Furthermore, taken together, all the regulations are trying to drive improved overall environmental performance but in a piecemeal manner. The EU does indeed have an overall strategy[xxi], however it has failed to adequately educate industry (certainly here in the US, at least, and arguably in the EU, since we see a similar approach being taken by European companies) on that strategy, its purpose, and its implementation.

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Industry Focus during Regulation Gestation

Historically the US Electronics industry did little lobbying of (the US federal) government until the mid-1990s. The AeA (formerly the American Electronics Association) began dabbling in environmental lobbying in the late '90s driven by large constituent companies like Apple, HP, and IBM. However, it not only proved ineffective in Europe (as evidenced by the ultimate cost to industry – when asked about this they will accentuate the positive, saying they made great strides by keeping the list of restricted substances to only six), but they – through perhaps little fault of their own – failed to provide their constituents, and the industry at large, with adequate information about what was happening during this early period, and what was coming up on the environmental regulation front, particularly from Europe. As evidence of this, AeA sponsored a "road show" seminar that traveled around the United States in 2003 and 2004 to try and make industry aware of the new RoHS and WEEE directives from Europe. The audiences were, according to one of the presenters, far smaller than expected or desired. Design Chain Associates as well began a series of similar "road show" seminars in 2004 and continued them through 2005; despite extensive advertising and support through multiple marketing channels the attendance at any given seminar reached 50 attendees only at the centers of the electronics industry – Silicon Valley and Northeastern Massachusetts. To put this in to perspective, there are on the order of 20,000 electrical and electronics manufacturers in the US alone[xxii].

The fault was not entirely that of AeA and the other Electronics industry trade associations, or the European Union. The industry was suffering through the deepest depression since the 1970s (that depression was caused by NASA's termination of the Apollo program) from 2001 through 2002 with little growth in 2003 and 2004[xxiii]. Management was more focused on keeping their company's doors open and meeting payroll than worrying about something that would affect them in 2006, and many companies simply believed the regulations did not apply to them. Even management at large computer manufacturers with extensive awareness and involvement in the AeA's lobbying and seminars struggled to fund RoHS compliance projects during this time period. In fact, nearly half of all electronics companies we surveyed in mid-2004 were unaware of or had only "heard of" RoHS[xxiv].

Even in the EU awareness of the RoHS and WEEE directives was poor, particularly among small and medium sized enterprises (SMEs), as late as April 2005, more than two years after it had been passed in to law and 15 months before the directive (and associated local member state regulations) was to come in to force. The UK Department of Trade and Industry (DTI, now BERR: the Department for Business, Enterprise and Regulatory Reform) was so shocked by the number of SMEs that were unaware that they put out a tender offer to hold workshops throughout the UK to raise awareness[xxv]. Even today, the UK Environment Agency says only a third of small businesses are even aware of WEEE[xxvi].

Automotive fared little better. Discussions with people at large US-based auto manufacturers and automotive supply chain companies indicate that they were essentially unaware of the ELV directive until at least 2000, which is when the regulation was passed. This even extended in to the REACH era, when US automotive companies were told in 2006/2007 by their EU-based subsidiaries that they had everything under control and to not worry about it. To their credit, by this time they understood that in fact there would be an impact and began to review and understand it.

US-based companies and their industry associations, and multinational industries of all countries, appear to have failed to comprehend early on why, and just how deeply, European Union-based environmental regulations would impact them so ultimately failed to pay adequate attention to this rulemaking or play an adequate role in the development of PTER. As evidence of the extent that this continues to the present day, a recent survey by PriceWaterhouseCoopers (PwC) on REACH awareness around the world concluded that "… two in five companies have limited awareness of the regulation and one in four executives feels Europe's newest rules on chemicals and their safe use will have no impact on operations."[xxvii] A graph in the report indicates that only around 30% feel their companies have a high level of awareness.

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Industry Reaction to ELV and RoHS

The reaction to ELV and RoHS was two-fold: first, individual companies had to understand the regulation, how it could impact their products and business, and prepare themselves to comply. Second, as with other regulatory requirements (such as for safety or electromagnetic interference), standards bodies are driven by member companies to initiate standards development processes where it makes sense. So people at affected companies, once they themselves learned about the regulations and had adequately informed those with a need to know (particularly their management to get funding; colleagues in their, and other, departments that would be impacted; and then their supply chain to get support), had to extrapolate the impact to others in their industry or supply chain and bring the potential need to standardize to others, typically at industry standards bodies.

This clearly does not happen overnight. In both Electronics and Automotive (as well as other industries), standards only start to become possible when consensus among the larger or more influential companies emerges that they are indeed necessary. What follows is an overview of some of the standards and their timelines and effectiveness that are related to, primarily, ELV and RoHS.

Standards and Guidance Development

Given the situation mentioned above in the industry focus section, it's not surprising that it took the automotive industry until 2002 to unify their diverse and divergent attempts to obtain substance information from their supply chains and agree to produce the IMDS (International Material Declaration System) database[xxviii], the intent of which is to enable a single location to hold all supplier-provided substance information for the automotive supply chain that is required by the ELV directive (and other industry or government requirements). Suppliers no longer have to deal with similar requests for information from different customers in different format but can simply load their data in to one system and be done with it.

Similarly, while the RoHS and WEEE directives were passed in to law in early 2003, the electronics industry did not begin to work on standardization efforts in many areas until much later. Nor, in fact, did any electronics industry body consult with its counterparts in the automotive industry on lessons learned, costs, or challenges to be faced. NEMI (at the time the National Electronics Manufacturing Initiative, later iNEMI, where "i" stands for "Inter"[xxix]) initiated a material declaration standardization project in June 2004, which was transferred to The Association Connecting Electronics Industries (aka IPC) in about May, 2005. This became the IPC 2-18 committee responsible for producing the IPC 1752 material declaration standard[xxx]. The first released version of the standard became available in March 2006, long after widespread adoption would have been desirable or even possible. In fact, today adoption stands at no more than 30%[xxxi]. As IPC 1752 was being developed, it became clear that automatic data transfer would be an important feature, given the potentially substantial amount of information for any given product. Rosettanet, an electronics industry standards body that focuses on supply chain data transfer standards, worked with the 2-18 committee to develop a new "Partner Interface Process", or PIP, called 2A13 which implements the data component of IPC 1752 in XML. A component manufacturer that was a founding member of Rosettanet and participated in the development and vetting of PIP 2A13 told us last summer, however, that there had not yet been any demand whatsoever for an automated 2A13 transaction.

To its credit, JEDEC (full name: JEDEC Solid State Technology Association) produced JEDEC Standard No. 97 (JESD-97 – "Marking, Symbols, and Labels for Identification of Lead (Pb) Free Assemblies, Components, and Devices") in May 2004 (superceded in January 2005 by IPC-1066, "Marking, Symbols and Labels for Identification of Lead-Free and Other Reportable Materials in Lead-Free Assemblies, Components and Devices"). This too was superceded in May 2007 by the IPC/JEDEC J-STD-609, "Marking and Labeling of Components, PCBs and PCBAs to Identify Lead (Pb), Pb-Free and Other Attributes." Granted, this standard has a relatively narrow scope[xxxii] but still has been very important and useful. IPC has produced a number of other standards for lead-free electronics assembly, and modified many pre-existing and widely used standards to incorporate lead-free solder concerns[xxxiii].

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The International Electrotechnical Commission (IEC) initiated Technical Committee 111 (TC111) in late 2004 and initially created three working groups:

1. WG 1 : Material declaration for electrical and electronic equipment
2. WG 2 : Environmentally conscious design for electrical and electronic products and systems
3. WG 3 : Test methods of hazardous substances

None has produced an approved, released standard to date. WG1 is targeting December 2009 for its standard (it was not initiated until January 2006); WG2 is forecasting July 2009 as a publication date; and WG3, which had a failed bid to release a final version of its standard in late 2007, is now forecasting December 2008 for its release[xxxiv]. IEC had previously, to its credit, produced guidance documents for the Technical Committees on addressing environmental impacts during standards development (guide 109, issued in 2003), material declaration (guide 113, issued in 2000), and "Environmentally conscious design – Integrating environmental aspects into design and development of electrotechnical products (guide 114, issued in 2005)[xxxv]. Unfortunately none has had wide distribution or, it seems, impact within or outside of the IEC technical committees.

ASTM International created its F40 Committee on Declarable Substances in Materials in early 2005[xxxvi], intending to create a series of test method standards that are complementary to the TC111 WG3 test method standard. While there is no defined timetable, ASTM has recently (May 2008) approved WK11200 (Test Method for Identification and Quantification of Lead, Mercury, Cadmium, Chromium, and Bromine in Polymeric Material using Energy Dispersive X-ray Spectrometry (EDXRF)), and WK15289 (New Test Methods for Test Methods for Analysis of Heavy Metals in Glass Using X-Ray Fluorescence (XRF)) is expected to be balloted this summer and published later this year[xxxvii]. F40 continues to work on a variety of other material standards as well and is not limiting itself to ELV and RoHS issues.

In March 2005 the Electronic Industries Alliance (EIA) issued the hastily written[xxxviii] EIA/ECCB-954 standard entitled "Electrical and Electronic Components and Products Hazardous Substance Free Standard and Requirements". Shortly thereafter, in October 2005, it was slightly revised and reissued by the IEC as IECQ 080000 "IEC Quality Assessment System for Electronic Components (IECQ) - Electrical and Electronic Components and Products - Hazardous Substance Process Management System Requirements (HSPM)". While hardly adopted in the United States and Europe to date, Taiwanese manufacturers quickly became the major customer for the consulting company responsible for authoring the standard (it helped that they also chaired the committee of the ECCB - Electronic Components Certification Board - that passed it; in fact, the primary author of the standard is now the ECCB President[xxxix]) due to Taiwan's legal requirement that any company shipping products to the European Union that are within the scope of RoHS had to prove that their business processes ensured compliance to RoHS; the Taiwanese government did not relish the thought of early prosecutions under the new law being of Taiwanese electronics companies.

Finally, a group consisting of one each American, Japanese, and European electronics industry associations initiated the Joint Industry Guide, JIG-101, in order to produce a single list that would contain all know restricted ("A" materials) and reportable ("B" materials) substances in electrical and electronic products in one place. They created initial drafts in 2004, with the final version issued in mid-2005. By that time the Europeans had dropped out of the group. The document served as the basis for part of the reporting capability of the IPC 1752 tool. Recently a move to revise and update the standard to include new substances of concern as well as reflect REACH-related issues has begun.

Similar to JIG, but predating it, the automotive industry started developing a list of declarable substances in 2000. This became effective in 2003 and finally morphed in to GADSL (Global Automotive Declarable Substances List[xl]) in 2005.

So here we are, over five years after the RoHS directive was passed and eight years after the ELV directive was passed and, besides assembly related standards, industry has created only a handful of relatively narrowly-scoped standards; and in the electronics industry none except J-STD-609 appear to be widely used.

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So why is this the case? In part, it was due to timing and the financial condition of the industry as described above. Other major factors include

- Prioritization – what is needed to continue shipping product. Industry cannot afford to allow a regulation to stop production. Standards development usually takes a notoriously long time so companies are forced to solve problems themselves and do so in their own way. This creates inertial resistance to adoption of standards once they are, in fact, available.
- Difficulty – While any standards development process has a degree of difficulty, certain standards require extensive inputs from a variety of different experts and few can see the entire picture. IPC 1752 was held up for a long time by company legal departments that apparently had little understanding of supply chain mechanics, for instance.
- Expertise – Manufacturers have lots of expertise in assembly, mechanical engineering, and material science; they have relatively little in environmental regulation, material disclosure, and design for environment. Since the dawn of the industrial revolution, and perhaps even before, there has been little or no direct requirement for environmental performance in most manufactured products. Therefore there is no infrastructure (such as university programs, information standards, etc.) or knowledge built in to industry to be able to deal coherently and competently with these issues. There is no place to go for environmental expertise, as there historically has been for manufacturing and design expertise[xli].
- The extent of Industry involvement – the more companies, countries, and industries involved, the more challenging it is to achieve the consensus needed.
- Failure by the European Union to demand and fund the development of standards required to meet these regulations. In fact, most of the standards mentioned above were initiated in the US. US industry has a stronger history of taking voluntary approaches towards potentially regulated areas than does the EU so perhaps this is not as surprising as it otherwise might be.
- Company organizational "silos": Goals within companies are not optimized around product lifecycle, but around functional areas. This stems from the fact that different departments often have separate budgets and disconnected objectives.. For instance,
    - Safety – we just set the requirements, engineering must determine how to meet them
    - Procurement – 2%/quarter cost reduction goals result in higher warranty costs due to purchasing cheaper, and ultimately lower quality, parts. Procurement meets their goal while warranty/field service doesn't.

  So anything that impacts the entire product lifecycle is likely to present difficulties in aligning agendas and goals within a given company.
- No coordinated mechanism to engage the supply chain – companies can deal one-on-one with suppliers quite readily but when the entire supply chain needs mobilization and engagement there is no way to do that, save repeated email blasts and phone calls. Needless to say there is also no industry-level or cross-industry mechanism to do this when, for example due to REACH, a massive call to action across supply chains (that very much overlap) is required.
- No cross-standards-body oversight and coordination. Standards Development Organizations (SDOs) are, in fact, often in competition with each other. Oversight including definition of standards available, standards needed, standards gaps, and assignments for standards development does not exist.

In summary, key challenges to rapidly developing useful standards include silos in companies, industries, and standards bodies. Environmental regulations cut across companies and now, with REACH (and soon with EuP[xlvi]), industries. Mechanisms to improve communication and focus approaches and efforts are needed if industry is to efficiently and effectively comply with these and future requirements.

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Industry GAP Summarization

Dr. Michael Wilson of UC Berkeley identified three "gaps" in his special report for the California Senate in 2006[xlii]. These are

1. Data gap – insufficient data on toxicity/ecotoxicity for governments and industry to identify hazardous chemicals.
2. Safety gap – a lack of information on how to identify, prioritize, and mitigate hazards, and
3. Technology gap – the lack of data on chemical toxicity results in a lack of market-based (and government) incentive to invent less toxic chemicals to compete against more toxic chemicals currently on the market.

Manufacturers that use chemicals and parts/materials/products that comprise chemicals downstream of the chemical manufacturers can not make the right determinations regarding environmental performance because they, too, have three basic sets of gaps when it comes to addressing product related environmental performance: Knowledge, standards, and communication. These can be summarized as follows:

1. Knowledge Gap
    a. Awareness and understanding is not "institutionalized" in industry or academia (or most governments)
    b. Implemented solutions are still suboptimal
    c. Can't apply partial knowledge to solve a complex problem: optimizing environmental performance of a system of thousands of substances

This gap stems from the "Data Gap", above - the historic unavailability of toxicity and other environmental data[xliii] on chemicals and chemical applications, as well as the equally historic lack of a market- or regulatory-driven need to use this sort of data for decision-making on materials and technologies for product development and manufacturing. With REACH (and perhaps also from voluntary efforts like the US EPA's Chemical Assessment and Management Program, or ChAMP[xliv]) we can expect more of this sort of data, but manufacturing industries will still lack the widespread knowledge required to actually use it to make product environmental performance decisions. Furthermore, the lack of expertise within product industries, particularly those far downstream of the chemical industry (such as electronics, aerospace, automotive, etc.), results in their being vulnerable to misinterpretation of available data or manipulation by agendas driven by the chemical industry or NGOs.

2. Standards Gap
    a. Regulation comes in to force before industry standards are in place
    b. No common methodologies – creates huge inefficiencies
    c. No oversight of SDOs

While REACH is expected to produce a prodigious amount of toxicity/ecotoxicity data on many substances that is currently unavailable, the information will be provided in "dossiers" on the ECHA REACH-IT system. The information will not be in a machine-readable, mathematically or logically analyzable standardized format. Effectively, humans will have to read it, and render judgments. Standards are necessary to define formats for this sort of information, and perhaps other useful tools such as standard weightings and guidance on how and when to apply such weights.

It is only by consistent approaches to technical information can we even hope to every have metrics that are useable, for instance, by consumers to compare the environmental performance of two or more competing products. And it is only by focusing on the process by which we determine what is needed to develop such standards that we will understand what standards are needed, be able to identify useful pre-existing standards, and which need to be developed.

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3. Communications Gap
    a. No mechanism for coherent stakeholder communications
        i. Within companies, within industries, and between industries
    b. All manufacturing industries have to grapple with the same issues but have no platform to share information/approaches/ideas
        i. Particularly for REACH
    c. May in part be due to Knowledge gap
    d. ANSI/NAM Manufacturers Network[xlv] tries to address this, but is entirely volunteer-driven

There is no way to get the surprisingly extensive amount of data that must be communicated to/from the chemical industry to the downstream product user. The automotive industry has GADSL and IMDS for ELV, while the electronics industry has JIG-101A, PC 1752 and Rosettanet PIP 2A13 for RoHS, and they clearly do not overlap. REACH requires bidirectional communication throughout the supply chain and we have no way besides email, telephone, fax, postal mail, and face-to-face meetings to achieve that – all of those are time-consuming and produce unorganized, non-computer-readable data that is error-prone. On top of that, except for the ANSI/NAM Manufacturers Network, there is no way for different manufacturing industries to identify and resolve common problems and issues in a mutually acceptable and hopefully beneficial way.

Addressing These Challenges

So as the EU government rolls out new PTERs[xlvi] and other governments follow, it remains unclear whether

- The regulations are actually addressing the most important and compelling issues,
- The goals of these regulations are being met as efficiently and effectively as possible, and
- That the local or global environment is really being improved.

Implementation of these regulations has been and will continue to be extremely expensive for industry (despite estimates to the contrary from the European government, particularly for REACH[xlvii]). Governments, from the industry perspective, do not really seem to understand just how deep the impact of these regulations is, nor how unprepared for them industry really is. In fact, it is quite clear that industry generally does not understand this either. If it were well-understood, the energy for education, standards development, and a competitive approach to compliance would be far higher, as it is for new technologies, for instance. Nevertheless, as described above, environmental regulation has historically been viewed by industry as something to simply comply with rather than to compete on, and this is an enormous inertia that government must help industry overcome. Some of the key aspects for this include the following:

- Standard to support regulation must be considered for feasibility and implementation as regulation is defined

  Today the European Union produces regulations in this space without producing concomitant supporting standards. The Chinese Ministry of Information Industry produced supporting "standards" for their RoHS-like regulation after it was published, but more to support the lack of clarity and completeness in it than to help manufacturers to comply (but it had that effect as well, of course).

- Transparency amongst all stakeholders in the industry standards development process may require citizen oversight to achieve. The European Commission already funds ECOS – the European Environmental Citizens Organisation for Standardisation.[xlviii] There is no equivalent entity in the US.

  As implied above there are many areas, particularly in data communication and analysis, that require standards covering environmental performance alone.

- Governments need to be less "sovereign" when adopting regulations that already exist in other parts of the world and impact global manufacturers.

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Companies (electronics, in particular) often try to build one configurable product for distribution around the world in order to achieve economies of scale, driving costs down and quality up. Different implementations and requirements of laws that are otherwise attempting to accomplish the same thing complicate this process without adding value. An international process to vet and align regulatory requirements would, while potentially quite complicated by nationalist agendas and desires, enable optimization of both the regulation and its implementation.

- Educate users (engineers) at downstream companies on how to understand and use environmental properties in decision-making and problem-solving.

  The multidisciplinary nature of the challenge of environmental performance should be addressed at the university level. Engineers need basic education and guidance on how to think about this area, while universities need to churn out more green chemists/chemical engineers and toxicologists with awareness of how chemicals are used in products and the tradeoffs and considerations thereof. Areas of cross-fertilization and specialization include electronics/electrical engineering, mechanical engineering, material science, physics, chemistry, chemical engineering, business management, and many others.

- Incorporation of environmental performance metrics in final product specifications.

  There are many issues here, but the primary challenge is how to ensure a market-driven incentive for improvements in environmental performance. Standards are, of course, needed to ensure consistency and limit "greenwashing", while consumer education campaigns on how to interpret and compare environmental performance of one item over another, is critical to enabling consumers to make intelligent product choices. Public media campaigns/educational websites/etc., and buy-in and participation from the retail sector are critical for this to succeed.

The Biggest Challenge

All of the above are the "whats" to be done. The biggest issue, though, is the "How" – how can all of this be accomplished? American industry, in particular, has turned in the past to public/private partnerships to address major challenges. For example, at the height of the fear that Japan's relentless improvements in quality performance would result in the United States losing its lead in semiconductor technology, the industry joined together with the federal government and developed Sematech to pool resources for pre-competitive research and technology development. Sematech has long since become an industry-only initiative but it remains an example of a successful partnership that netted positive long-term results. The tension between industry and government – the regulated and the regulator - however, makes this difficult. People from one have a poor understanding of what the other understands, is trying to accomplish, and needs. And in an area that is new to both, like PTER, the challenge is compounded.

But the fact is that we have one planet and its resources are clearly not unlimited. Working together in partnership to address enormous international challenges may be the only viable way to deal with issues larger than any one person, company, industry, or government. A public/private partnership that spans industries and governments is not a new concept – the World Bank has a Global Public-Private Partnership (PPP) in Infrastructure[xlix] - but it does not appear to be a common concept either. Its focus is on various types of infrastructure, such as social, transportation, education, and so on. The question is whether this would be a reasonable approach to address improvements required in industry infrastructure.

Conclusion

In this paper we have endeavored to show how the combination of a new type of environmental regulation, lack of industry awareness and comprehension, and poor or non-existent communication paths between and within governments, industries, standards bodies, companies, and educational institutions has resulted in a very tenuous, and not very effective, ability for industry to comply with said regulations. Governments responsible for

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these regulations should understand that industry is surprisingly ignorant of the big picture frameworks that incorporate the individual regulations with which they must comply. And industry should take a far more considered approach to environmental performance improvement if they are ever to achieve truly competitive performance in the environmental arena and reduce the antagonism with governments and NGOs in this area. To fill the fundamental gaps that industry has requires cooperation with governments, between different manufacturing industries and disciplines, with and within standards development organizations, with NGOs, and with the educational system. Fundamental infrastructures are required but are missing today. By addressing these issues we can enable the move from simple compliance to true competition. This will incentivize and drive environmental performance improvement of products from all manufacturing industries and their supply chains worldwide.

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i See the EPA's website: http://www.epa.gov/air/caa/
ii See the EPA's website: http://www.epa.gov/lawsregs/laws/cwa.html
iii See the EPA's website: http://www.epa.gov/lawsregs/laws/tsca.html
iv See the Chemical Abstract Service, a division of the American Chemical Society, at http://www.cas.org
v See the OSHA website; for instance http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10099#1910.1200(g)
vi See directive 94/62/EC - http://ec.europa.eu/environment/waste/packaging_index.htm
vii See http://www.leginfo.ca.gov/pub/07-08/bill/asm/ab_1101-1150/ab_1109_bill_20071012_chaptered.pdf
viii See http://ec.europa.eu/environment/waste/elv_index.htm
ix See info on both RoHS and WEEE at http://ec.europa.eu/environment/waste/weee/index_en.htm
x Consumers would be required to pay a $6 to $10 recycling fee when they purchase a product in the scope of the law – this is called "ARF", for Advance Recovery Fee
xi See, for example, http://b2b.sony.com/Solutions/product/VGN-NR280E/S#content2
xii Reliability of electronic products generally decreases with increasing temperature.
xiii See, for instance, "High Tech Trash" by Chris Carroll in the January 2008 issue of National Geographic Magazine - http://ngm.nationalgeographic.com/2008/01/high-tech-trash/carroll-text.html
xiv E.g. private conversation with Mona Blomdin Persson, Swedish Chemicals Agency, Director Environmental Objectives and Enforcement Department, Feb 22, 2008, Berkeley, CA
xv http://www.secinfo.com/d11MXs.v1efz.htm
xvi Greenpeace pushes removal of beryllium, PVCs, and all brominated flame retardants in game consoles at http://www.greenpeace.org/usa/news/game-consoles-no-consolation and tracks consumer electronics companies at http://www.greenpeace.org/usa/press-center/reports4/guide-to-greener-electronics-7
xvii See http://ec.europa.eu/environment/waste/elv_index.htm for more information on ELV
xviii See, for instance, http://ec.europa.eu/enterprise/eco_design/index_en.htm for more information
xix See the European Chemicals Agency web page on REACH at http://echa.europa.eu/reach_en.asp
xx http://www.purchasing.com/article/CA6552730.html
xxi Thematic Strategy on the Sustainable Use of Natural Resources, http://ec.europa.eu/environment/natres/index.htm, and the Thematic Strategy on the prevention and recycling of waste, http://ec.europa.eu/environment/waste/strategy.htm

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[xxii] See the 2002 Economic Census for Manufacturing at http://www.census.gov/econ/census02/data/us/US000_31.HTM#N334
[xxiii] Technology Forecasters, Inc. forecast reports, 2003 and 2004
[xxiv] See the report on the DCA survey as published in Electronics Supply & Manufacturing in Sept. 2004 at http://www.my-esm.com/print/showArticle.jhtml?articleID=45200009
[xxv] Private communication, Steve Andrews, DTI, April 2005
[xxvi] See http://www.computing.co.uk/computing/news/2209492/small-businesses-ignorant-weee
[xxvii] Waking up to REACH - http://www.pwc.com/extweb/pwcpublications.nsf/docid/d0e4ea679f0c73468525740800638ea7
[xxviii] Operated by EDS, the system can be found at http://www.mdsystem.com/
[xxix] See http://www.inemi.org
[xxx] See http://www.ipc.org/ipc-175x
[xxxi] Internal DCA experience with a project to collect full material content for a medical device company in IPC 1752 format in 2H2007
[xxxii] The standard covers printed circuit board, solder, and conformal coating materials only
[xxxiii] See http://leadfree.ipc.org/RoHS_3-4.asp for more information
[xxxiv] See the "Work Programme" on the TC 111 "Dashboard" at http://www.iec.ch/cgi-bin/procgi.pl/www/iecwww.p?wwwlang=E&wwwprog=TCboard.p&committee=SC&TC=111&submit=Submit
[xxxv] While not accessible outside IEC technical committees, the guides are available to members on the IEC website at www.iec.ch
[xxxvi] http://www.astm.org/cgi-bin/SoftCart.exe/COMMIT/COMMITTEE/F40.htm?L+mystore+tswc2812
[xxxvii] Private communication, Brynn Murphy, ASTM Staff Manager for F40, Feb. 11, 2008
[xxxviii] Private communication, Dennis Bradley, SBGI Corp, Feb 15, 2008. The team started writing the standard in late January 2005.
[xxxix] According to the ECCB website: http://www.eccb.org/about_us/contact_us.shtml
[xl] See http://www.gadsl.org/ for the actual list
[xli] All the key industry research entities (e.g. Bell Labs, etc.) are gone – research is no longer shared for the good of the industry, but is held closely as a competitive weapon. Industry cooperation and information sharing was much better in the '80s as we moved from through-hole to surface mount technology than it has been during the transition from lead-based to lead-free solder, for instance.
[xlii] See the report at http://coeh.berkeley.edu/docs/news/06_wilson_policy.pdf
[xliii] Such as energy used in manufacture, percent post-consumer waste content, etc.
[xliv] See http://www.epa.gov/champ/
[xlv] http://www.ansi.org/chemicals
[xlvi] See, for instance , the "Sustainable Production and Consumption and Sustainable Industrial Policy Action Plan" at http://www.euractiv.com/29/images/SCP%20draft%202404_tcm29-171962.doc and http://ec.europa.eu/environment/eussd/escp_en.htm
[xlvii] Total costs were estimated between €2.8 and 5.2 billion over 11 and 15 years respectively. See http://ec.europa.eu/environment/chemicals/reach/background/i_a_en.htm#env_benefits for more information.
[xlviii] See http://www.ecostandard.org
[xlix] http://info.worldbank.org/etools/PPPI-Portal/index.htm

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