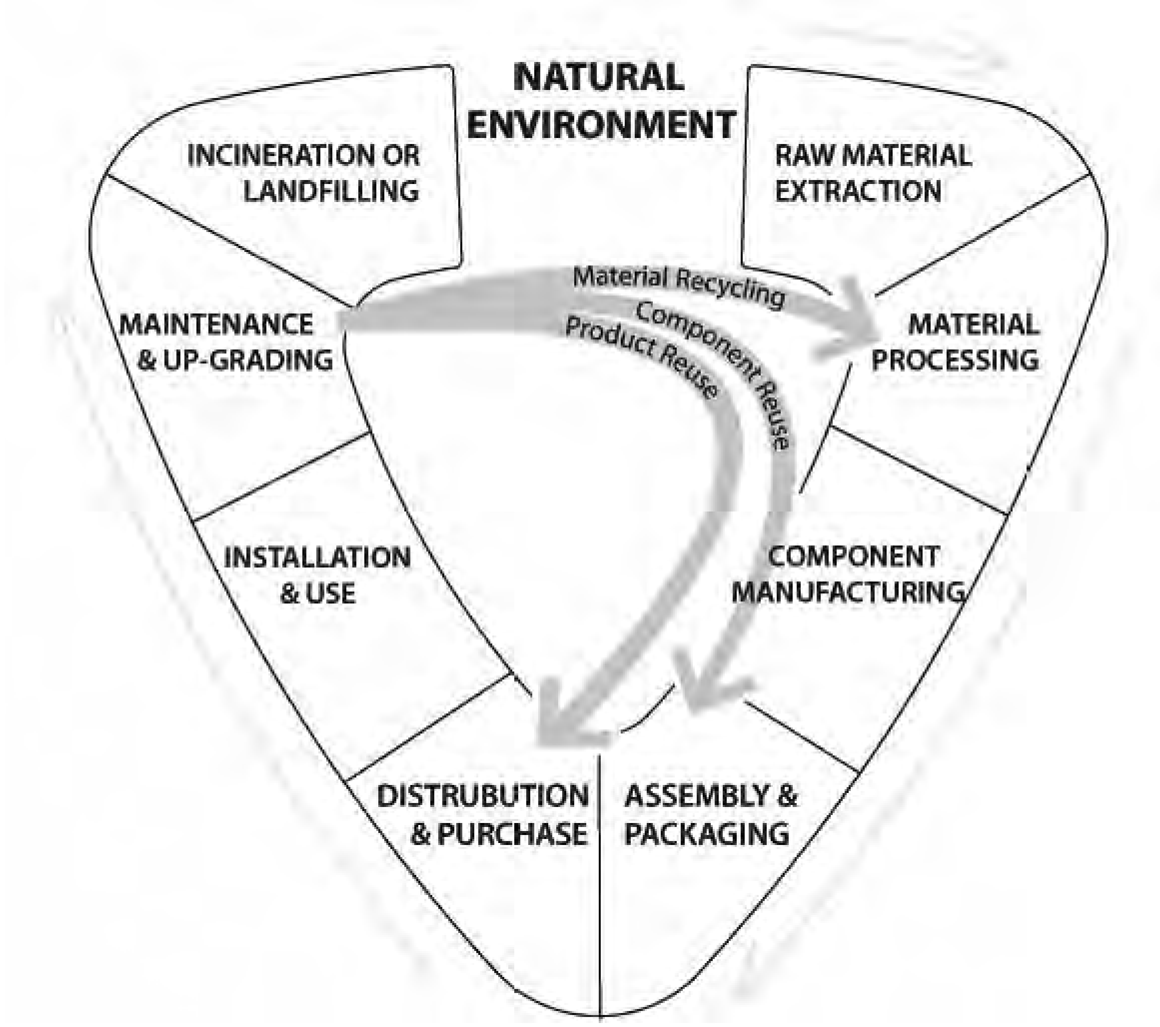
Chemicals in electronics

Computers and mobile phones can contain over one thousand different substances. The main hazardous substances that could be found in electronic products are: lead, mercury, cadmium, zinc, yttrium, chromium, beryllium, nickel, brominated flame retardants, antimony trioxide, halogenated flame retardants, tin, polyvinyl chloride (PVC) and phthalates.

In addition, electronic products contain valuable metals such as gold and copper that are valuable for recyclers to extract. Plastics recycling are also steadily increasing.

Electronic devices are manufactured, used, and waste-managed according to a life cycle, which can be described as in the figure below



Electronics products consist of components, from a few to several thousand, each of which has its own life cycle. Mobile phones can be said to consist of nine basic parts:

- Circuit board/printed wiring board
- Liquid crystal display, LCD
- Battery
- Plastic casing
- Antenna
- Keypad
- Microphone
- Speaker

• Accessories (such as adapters, headsets, carrying cases, and decorative face plates)

An electronic device such as a laptop computer is made up of over a thousand separate components. The parts can be classified as follows:

• *Housing & Input*. The housing often is plastic, so are the input devices such as a keyboard or a mouse pad.
• *Display Screen*. Display screens are usually LCD screens. LCDs have displaced cathode ray tube (CRT) displays in most applications. In addition, OLED (organic light emitting diode) screens are becoming increasingly used. However CRTs are still common on the market, in second-hand markets and in e-waste.
• *Semiconductor ICs*. For example the CPU, memory and other specialized chips such as a wireless network chip.
• *Printed Circuit Board*. These are rigid boards that all components are soldered on to. Printed Circuit Boards include motherboards and memory modules.
• *Mass Storage*. Often called a “hard disk drive”, where most of the generated data such as the documents, images etc. and program files
are stored.
• *Optical Storage*. Very similar to hard disk drives, with the addition of a laser based component which may use certain hazardous substance in the glass.
• *Connectors*. The connectors can be internal, such as the power supply to a hard disk drive, or external such as USB ports.
Connectors need to be heat-resistant, able to withstand temperatures of up to 260°C, in order to be soldered on to PCBs.
• *Cabling (Internal and External)*. Internal cables connect components as shown in the example above. Cables are also used externally in the power cord.

From the perspective of transferring information, each actor in the product chain has a role to play in passing on information to the next actor downstream, as well as communicate feedback and information on use and exposure etc. to their supplier upstream. Any actor not passing on relevant information (i.e. relevant at any point in the supply chain further downstream) creates a gap in the transfer of information in the supply chain. This study will focus on the following categories of actors as target-groups for the purpose of in-depth interviews on their perspective on information on chemicals in electronic products:
• Chemicals and/or material manufacturers
• Components manufacturers
• Producers of end-products, i.e. brand names and Original Equipment
Manufacturers (OEMs)
• Consumers and public interest organizations
• Waste handlers, formal sector
• Waste-handlers, informal sector, often in developing countries
• Government Agencies

Chemicals present in electronic products

Analysis of the chemicals present in electronic products is not a simple matter. Computers and mobile phones can contain over one thousand different substances.[15] Some of the materials used are valuable resources, such as gold, copper and silver. Other ingredients are hazardous.

There are also cases where substances are hazardous as well as valuable, such as copper.

The main hazardous substances found in electronic products are: lead, mercury, cadmium, zinc, yttrium, chromium, beryllium, nickel,

brominated flame retardants, antimony trioxide, halogenated flame retardants, tin, polyvinyl chloride (PVC) and phthalates.

The table below summarises the components in which these chemicals are most commonly used.

Drivers for recycling

Simple economics illustrate the why electronic waste is deemed so valuable:

The economic level for a gold mine is approximately 5 grams (0.18 ounce) gold per tonne of ore. Discarded electronics, such as mobile phones, can yield 150 grams (5.3 ounce) or more per tonne, according to a study by Yokohama Metal Co Ltd.[16] The same volume of discarded mobile phones also contains around 10% (100 kg/220,5 lb) of copper and 0,3 % (3 kg /6.6 lb) of silver, among other metals. By comparison,

Boliden reports an average copper content of 0,36% in the ore of their mine in Aitik, Sweden

The recovery of gold, silver, copper and palladium can thus be economically profitable, and these metals are therefore commonly recycled.

Since these four metals represent more than 90% of the economic value of a typical printed circuit board, recycling companies have little incentive to target other substances. Metals such as indium and ruthenium, which are increasingly common in electronics, are thus not commonly recovered at present. Manufacturers' pursuit of smaller and lighter electronic products with higher capacity has led to the introduction of an increasing number of rare materials, especially metals. For example, the composition of a processor from Intel Corporation has increased from 12 elements in

1980 to 16 elements in the 1990s, and 44 by 2000 . Currently, recycling companies can recover only a few of these elements.

Valuable metals are important to recycle from a strategic resource perspective. The global reserves of some of these elements are very small and the opportunities for finding good substitutes are limited. In the case of gold and silver, the electronics industry is only using a few percent of the global mining supply, but for some of the rare metals, such as indium and ruthenium, the electronics industry is the dominant user.

It is therefore important to make sure that the recycling system for electronic products can also recover rare metals.

As the price of resources required for the production of virgin plastics increases, it is expected that recycling rates will further increase.

Some of the benefits include:

- reduction of energy consumption;
- reduction of oil consumption;
- reduction of water usage;
- reduction of carbon dioxide generation;
- reduction of usage of (hazardous) chemicals

Handling of electronics and Potential release of chemicals

Exposure to chemicals during production

Workers, consumers and communities are exposed to chemicals in consumer electronics throughout their life cycle, from manufacture through use and disposal. The emphasis in discussions on health and environmental impacts from electronics is usually on the end-of-life phase, in particular during informal waste management.
However, problems occur during the production stages as well, but information on these chemicals and their health impacts are scarce at best.
Studies have demonstrated high exposure to carcinogens and reproductive toxicants during production, including solvents, heavy metals and epoxy resins among electronics workers and increased rates of spontaneous abortion and birth defects among women working in semiconductor fabrication. In addition, several studies over the past two decades have shown that electronics workers have a significantly elevated risk of lung, pharyngeal, nasal, breast, bladder, and brain cancers.
Communities located near semiconductor manufacturing have suffered health impacts from direct contamination of their environment.
Studies have been looking at the link between solvents and other chemicals leaked from semiconductor manufacturing plants in San Jose, California and increased rates of spontaneous abortions and congenital malformations among infants exposed during pregnancy.

Exposure to chemicals in the use phase

Evidence is growing that exposure to (hazardous) chemicals also occur during the use-phase of electronics. Sampling of household dust indicates that levels of dioxins and furans in indoor environments are increasing. Studies looking at house dust and office dust in Japan found high levels of polybrominated dibenzofurans (PBDFs) in these environments.
Other studies have looked at the debromination of flame retardants such as decabromodiphenylether, DecaBDE, a flame retardant used in a wide range of applications including electronics. For example, one study looked at the formation of PBDFs in flame-retarded plastics exposed to normal sunlight.
The researchers found that in high-impact polystyrene, HIPS, containing
DecaBDE, the PBDF concentration increased by about 40 times after 1 week of exposure. Also, in TV casings with DecaBDE, PBDF concentrations increased continuously during the experiment. The researchers concluded that more attention should be paid to the fact that
PBDFs are formed by sunlight exposure during normal use as well as disposal / recycling processes of flame-retarded consumer products.
In addition, high levels of polybrominated dibenzodioxins (PBDDs) and
polybrominated dibenzofurans (PBDFs) have been found in plastic TV housing, demonstrating the presence of dioxins and furans in the usephase of products containing plastics with brominated flame retardants.
It is very likely that a significant share of the exposure described above comes from the presence and use of consumer electronics. Such findings raise concerns for risks during the use phase as well as in waste-management.

Recycling practices in the formal sector

One can divide the recycling of PCs into three steps. In step one, collected PCs are manually dismantled into body (plastic, iron),
CRT, unit parts (HDD etc.), cables and other components. At this stage, usable parts are separated, checked and reused as service parts. In step two, metal and unit parts are shredded and separated into iron, aluminium, copper, etc. Plastic parts are separated according to type of plastics.
CRTs are dismantled manually and sorted into metals and glass. In step three, CRT glass is recycled to be reused in CRT displays by CRT manufactures.
Gold, silver, and other precious material are refined from printed circuit boards by metal refineries. What is not used from the discarded printed circuit boards is recycled into road pavement materials. Other electronics such as mobile phones are recycled in a similar fashion.

Recycling practices in the informal sector

Most e-waste in developing countries is handled by the informal sector.
In some countries this work is systematised to include waste pickers, collectors, small middlemen, and larger middlemen that sell the recyclable parts to the material recycling industry.
In other developing countries this informal work is not as organized but something that is done on a household level. It is a common feature of the informal waste sector in developing countries that it consists of the poor with little or no formal training.
The practices of e-waste management in developing countries as well as the impacts of such practices have been particularly well-documented for Guiyu in China, and the data referred to in the following sections is to a large extent constituted by, but not solely from, studies in Guiyu. The town is made up of several villages located in the Chaozhou region of Guangdong Province, 250 km northeast of Hong Kong. Since 1995, what was traditionally a rice-growing community has become a recycling centre for e-waste arriving from overseas.
It should be noted however, that as data is generated in other regions in developing countries where e-waste is an ever-increasing problem, similar pictures emerge. The interviewees in this report as well as previous studies describe elevated concentrations of heavy metals, dioxins and other hazardous substances in the dust, air, soil, fresh water and sediments surrounding sites and workshops where e-waste is treated in developing countries.
Guiyu is increasingly becoming the standard, rather than the exception.
Often, electronic waste is disassembled directly at dump-sites or small workshops in the informal sector, where there is no real control over the materials processed, the processes used, or the emissions and discharges from these facilities.[37] The primary goal of such recycling operations is the recovery of valuable materials, such as gold and copper, and the goal is pursued with little or no regard for the environment or human health.

Melting and extruding plastics

Plastics are processed in similar ways in many developing countries.
They are manually removed from e-waste and mechanically shredded.
The next treatment step is either some kind of separation (e.g. by colour or density) and/or further grinding. These operations are often carried out in rooms with little ventilation and no respiratory protection.[44]
Many interviewees to this report describe how in developing countries e-waste parts are burned on open fires, at dumpsites as well as in workshops, to recover metals from the plastics in which they are encased.
This includes plastic coated wires, other complex components as well as unwanted, discarded scrap.

Exposure to chemicals during recycling

There are severe, well-documented problems connected to the informal recycling of electronics, especially arising from open-fire burning of electronics components in developing countries. However, the release of e.g. additive brominated flame retardants, and subsequent human exposure to them, is not just restricted to informal e-waste practices, but occurs also in formal recycling processes.

Formal

Studies on release pathways and exposure to workers in recycling facilities in developed countries have documented the release of hazardous chemicals present in recycled e-waste. Studies have demonstrated higher levels of PBDEs in the blood of workers employed in the formal ewaste recycling sector, for example in e-waste recycling facilities in Sweden and Norway. Elevated levels of polybrominated diphenyl ethers, PBDEs and other brominated flame retardants have also been reported in air samples collected at a European plant involved in the recycling of e-waste, particularly in the vicinity of shredding equipment.

The study found extremely high concentrations of tetrabromobisphenol A, TBBPA, in the indoor air. The brominated flame retardant
decabromodiphenyl ether (DBDPE) was also tentatively identified in air samples from an e-waste recycling facility in Sweden.Furthermore, health hazards from the electronics recycling programme operated by the US Federal Prison Industries have been documented Such findings confirm that although informal e-waste management is in general carried out without consideration of human health and the environment, it does not mean that formal e-waste management is per definition safe.

Even under optimal circumstances, in modern facilities, there is a risk of exposure and e.g. dioxin formation when treating material containing hazardous chemicals, for example brominated flame retardants, (BFRs).

Filtering the flue-gas from incinerators in order to capture fly-ash can be used to reduce escape of such chemicals. However the problem of how to handle and store the filters, to ensure that the captured dioxins are not released at a later stage, remains.

Informal

The rudimentary informal sector recycling techniques described above, coupled with the amounts of e-waste processed, have already resulted in adverse environmental and human health impacts in the developing countries receiving e-waste, such as China, India, Nigeria, the Philippines and Ghana.

For example, environmental pollution is a likely outcome of the breaking and handling of CRTs. The open-air storage and dumping of
CRTs raise concerns regarding the possibility of lead contained in the CRT glass leaching out into the environment. [51]

Heating of printed circuit boards for de-soldering and removal of chips undoubtedly exposes the worker to fumes of metals, particularly those in solder (often lead and tin), and other hazardous substances that can be potentially released during such treatment.

Since open fires burn at relatively low temperatures, which is most often the case when burning e-waste in open fires, the release of pollutants are significantly higher than in a controlled incineration process. Experimental studies have documented the formation of dioxins and furans through open burning of wires and printed circuit boards

Studies have shown that copper, which is present in printed circuit boards and cables, acts as a catalyst for dioxin formation when halogenated flame-retardants are incinerated. When incinerated at low temperatures
(600-800°C) these brominated flame retardants can lead to the generation of extremely toxic polybrominated dioxins (PBDDs) and
PBDFs

A number of studies have shown that inhalation and dust ingestion as particularly important routes of human exposure to dioxins, lead, copper, cadmium[64] polybrominated diphenyl ethers, PBDEs, polychlorinated biphenyl, PCB, chromium.[65]

The exposure may have an effect on levels of thyroid-stimulating hormone and cause genetic damage, respiratory ailments, skin infections, and stomach diseases.

Overview of CiP information Systems

International industry systems for sharing Information

Industry-wide initiatives have been set up which are international in their scope. These include the Joint Industry Guide (JIG), the International Electrotechnical Commission (IEC) material declaration standards and the Global Product Strategy (GPS) chemicals portal.
The JIG is a material declaration standard developed by and for the global electronics industry. It is a business-to-business communications tool which applies to products and subparts relevant for manufacturers in the electronics industry.[68] The aim is to facilitate reporting on material content information across the global electronics supply chain.

"This Guide represents industry-wide consensus on the relevant materials and substances that shall be disclosed by suppliers when those materials and substances are present in products that are incorporated into electrotechnical products.
The Guide benefits suppliers and their commercial customers by providing consistency and efficiency to the material declaration process and will promote the development of consistent data exchange formats and tools that will facilitate and improve data transfer along the entire global supply chain [...] "
"This Guide contains:
- the lists of substances for disclosure when contained in electrotechnical products;
- the threshold levels for substances in electrotechnical products, equal to or above which the quantity of the substance must be disclosed;
- the regulatory requirements that establish threshold levels for electrotechnical products, where appropriate;
- a set of data fields for information exchange."

National / Regional regulation and initiatives

Many of the waste-related policies introduced over the last few years have been based on the principle of extended producer responsibility (EPR). The idea behind this principle is that manufacturers have a responsibility for their products, and the environmental impacts related with these products, which goes beyond the production stage. The EPR principle stresses especially manufacturers' responsibility for the endof-life treatment of their products. This responsibility can manifest itself in different ways, but it usually includes either a physical responsibility to take back the product after its use, or a financial responsibility to payfor recycling or waste treatment carried out by another company. The
producer responsibility can also include a requirement for the manufacturer to disclose information needed for safe use, handling, recycling and disposal. This *informative responsibility* makes producers responsible for providing information on the product or its effects at various stages of its life cycle and could thus include CiP information

The European Union

Although neither specifically focused on products nor any particular sector, the European Union REACH regulation on chemicals has since its adoption in 2007 had a global impact, on legislation in other part of the world as well as on how communication on chemicals and chemicalscontaining products is perceived, carried out and handled.

REACH obliges manufacturers and importers to register and provide basic information on the intrinsic properties of all chemicals produced or imported in volumes above one metric tonne per year on the EU market. The information requirements increase with the volume of the registered chemical.

CiP information in manufacture and use

Most stakeholders who were involved with creation of both mobile phones and PCs used the same information systems both for products and for chemicals and materials. Thus, no effort is made here to separate information systems into categories based on mobile phones, PCs, or their various components. Actors at different locations in the supply chain, namely producers of chemicals and materials and the downstream users of these products do however, reference different sets of information systems. These two broad groupings of business will be discussed separately.

The following provides a simplified description of stakeholder functions and interactions within the chain:

- The chemical producers create the basic chemicals, blends of chemicals, and materials (e.g. plastics and polymers for product casings, plating chemicals, solvents, paints and coatings, and metal finishes) that form the basis of mobile phones and PCs.
- The above materials are supplied to the large web of components manufacturers, who make everything from moulded plastic casings to disc drives and circuit boards. There are commonly several tiers of suppliers in between the chemical producers and the brand owners.
- Components are assembled into finished products for brand owner companies who then sell the final products to other businesses and/or consumers.
- NGOs and consumer interest groups are active along this chain, for instance in informing brand owners about appropriate and safe selection of chemicals, and in helping consumers obtain the information they need to safely use or dispose of the final product.

Needs and access to CiP Information in the product chain

Companies use CiP information in many ways. One of the most common and important uses cited by interviewees was to keep up to date on the latest information on chemical hazards and risks because it is “good for business.” These companies prefer to stay at the forefront of the industry where they are able to develop new alternatives and substitutes of high quality within an adequate timeframe, rather than reacting to new regulations once they are enacted. Generally, the companies participating in this research adopt voluntary restrictions as opposed to waiting for regulatory action that may require restrictions, and they seek out available sources of information that will help them determine which chemicals may be of concern in the future. In the words of one components manufacturer: "It is usually more cost effective to be proactive than it is to wait until a requirement lands on your desk. So we try to be strategic. It's as simple as that." Such a strategy may also provide a point of differentiation from the competition by eliminating problem chemicals from their products before others do. In addition, seeking out information on chemical hazards may allow companies to restrict chemicals that they perceive to be dangerous, regardless of the potential for regulation.

A few interviewees from different locations in the supply chain mentioned that there is an "informal" type of information system or information exchange that occurs within the electronics sector through a networking approach. Actors at various points in the supply chain meet to talk about where the industry is heading in the coming years and which chemicals and materials will be needed or should be developed for future products. They also participate in standardisation committees and other industry associations to keep up-to-date and/or help guide the direction of the industry. This future planning or road mapping may occur among many actors from different companies and organizations throughout the value chain, between only a few specific actors, or within a single company. It can take many years to develop a new product or modify an existing one, so some companies see networking within the value chain as critical to their business, both in understanding other value chain actors' product needs and in learning about which chemicals should be avoided in products.

Producers of chemicals, chemical mixtures, and Materials

Chemical producers described two main ways of communicating information about their products. First, there is direct communication with their customers about specific products that the customers are interested in or have purchased. Information provided at this stage is referred to as a "push" type of information, since specific, detailed information is directed from the chemical producer to a particular customer.

The second form of communication is not directed toward any particular actor, and is referred to as a "pull" type of information. Information communicated by this route is freely available to the public, so any person or group who wants it can obtain it, often via the Internet. Regarding dissemination of this information to interested parties, some interviewees noted that they do not know how far the information they provide to their direct customers travels down the supply chain, or exactly who uses the "pull" type of information.

The chemical producer's main communication is often with its first customer downstream in the value chain, e.g. the electronics components manufacturers who make items such as shell cases, but there is occasionally communication with actors farther downstream. For instance, retailers sometimes have questions about chemicals used in final

products.
The chemical producers emphasised that it is very important to them that their immediate downstream customers have a full understanding of how to safely use and handle the chemicals or products they receive. The producers said that they risk assess every chemical or product they sell to create a set of acceptable uses in which the chemical or product will be safe. They then gain an understanding of each immediate customer's proposed use of the chemical or product before selling it to ensure safe use.
Some producers also have web pages that their customers can access for specific information on the chemical products they purchase.

Downstream Users: Components Manufacturers and Brand Owners

Downstream users of chemicals have additional information systems and strategies that they use regarding CiP information. This group aims to comply with all relevant regulations. In addition, the representatives from the companies interviewed also said that they strive to go beyond regulations by voluntarily restricting certain chemicals that may be used in the electronics industry. A chemical may be voluntarily restricted for a variety of reasons, including negative public perception, a real threat of harm, or likely future regulation.
The relevant regulated and voluntarily restricted substances are typically found on companies' restricted substance lists, RSLs, which are usually updated annually, and often include substances that are banned or restricted from products as well as those that are in the process of being phased out. Each of the participating companies consult many of the information systems described in chapter 4 in deciding on which substances to include in their RSLs; each company uses a unique combination of non-regulatory information systems in deciding which substances to voluntarily restrict. One brand owner company said that it also performs a life cycle analysis on its products to help determine which chemicals to put on its banned and restricted lists. This analysis includes the acknowledgement that recycling can occur in substandard ways/conditions in some contexts, and products are designed to be safe based on this reality. Some RSLs are publicly displayed on company websites, but most are only shared with the companies' suppliers. It is likely that no two company RSLs are identical.
As one example, a components manufacturer listed the following information systems and sources as being important in helping it identify chemicals for its RSL:

- International conventions
- Laws and regulations
- Customer RSLs and other specifications and requirements
- Industry standards
- Information about possibly hazardous material contents provided by third-party organizations that inspect, verify, test, and certify materials
- NGO reports regarding hazardous substance control
- Reports from other experts or institutes dedicated to chemicals Management

Consumers needs and access to CiP information

The NGOs and consumer interest groups who were interviewed for this study described consumer access to CiP information as a dire situation. One interviewee said that the situation might be slightly better in the case of consumer electronics because, though most consumers are primarily interested in features, electronics magazines also include information about environmental and safety concerns in overall product assessments. Since electronics products tend to be more expensive than other daily use items, consumers might be more likely to seek out product reviews in electronics magazines, and will also see the information about environmental and/or health concerns.

In addition to information presented in electronics magazines, environmental excellence schemes such as the EU Eco-label may provide a useful “shortcut” for consumers to make informed product choices. The appropriate eco-label on a given product will signal to consumers that they do not need to look for information about possibly hazardous chemicals in the product. However, interviewees pointed to a current widespread problem of green-washing, which can make a dependence on ecolabels less than reliable for identifying products without chemicals-related environmental or health concerns.

RAPEX, the EU’s rapid alert system for dangerous consumer products, was also mentioned by consumer interest groups as a helpful CiP information system. The number of RAPEX notifications related to chemical risk in consumer products continues to increase. However, this system was designed more for authorities and NGOs to know if certain products should be recalled or taken off the market due to serious health or safety risks than for use as a consumer tool for product selection. Further, consumers cannot access much of the information available on RAPEX.

REACH, on the other hand, was mentioned by two interviewees as being a disappointment. These interviewees do not feel that it is a useful information system in protecting consumers from hazards in products because they think its procedures are too lengthy and complex, and dissemination of chemicals data has not been as wide as was hoped.

Gaps and obstacles to CiP information exchange

Proprietary information can disrupt flow of information in both directions

Proprietary information was discussed in all interviews, and was often mentioned as an obstacle to flow of CiP information. Interviewees had strong opinions on proprietary information, and it was a controversial topic. While no consensus among stakeholders was reached for this report, the varying opinions are presented here to illustrate the differing views on the topic.

Downstream users saw proprietary information as an obstacle to flow of chemicals information in the supply chain, saying that some of their suppliers refuse to submit information on chemicals for reasons of protecting proprietary information. Some downstream users said that this protection sometimes extended to basic formulations that were standard in the industry, and others suspected that claims of proprietary information were sometimes used to avoid filling out long forms for complex devices. Downstream users were sympathetic to upstream actors' unwillingness to disclose proprietary information to varying degrees, and they described different ways of dealing with proprietary information.

A global standard for CiP information is needed

Several companies stressed that a global reference for them to use in design of products would be incredibly useful and would lead to significant cost savings across the industry. Currently, discussions about chemical use are country-by-country, and it is difficult for global actors to keep up with the evolution of chemicals policies around the globe. A common standard for chemicals use and information transfer would simplify design, production, and distribution of electronics. Some interviewees noted that they thought the United Nations would be an appropriate organization to design such as system.

A few interviewees mentioned that some stakeholders are expecting REACH to provide direction for the global electronics sector, but that REACH does not actually serve that function. One interviewee explained, "REACH covers a very small fraction of what needs to be covered in terms of toxic chemicals and reporting on non-toxic chemicals in products. While it is a step in the right direction, it does not have application in a mass production environment."

If a global standard were to be created, an obstacle that must be overcome is that different actors in the value chain have different expectations as to what the standard would include or exclude. Even in these interviews, it was apparent that different actors have dramatically different ideas about which chemicals should not be used in products, how much information should be provided about product content, etc. For instance, one downstream user that is often at the forefront of phasing out undesirable chemicals from its products said that its proactive approach is frowned upon by some other industry actors that are not as enthusiastic about adding additional substances to their RSLs. Another downstream user stressed that the level of protection regarding allowable chemical use in products should be targeted at pregnant mothers, a level that other actors may not find appropriate. This interviewee also suggested that information about a chemical's toxicological profile should be provided to users in the supply chain. The point is that a global standard would need to have the support of at least a reasonable fraction of industry in order to be effective.

Global supply chains are huge and complex

Several downstream users, especially brand owners, discussed the vast and complex nature of their supply chains. Brand owners often do not design and create all of their product components, and they may have several tiers of subassembly manufacturers involved in production of their goods. Thus, it may be difficult for them to control all of the chemicals used far upstream in the chain. An interviewee from one company gave a hypothetical example where a supplier using a hazardous chemical could be five or more tiers upstream in the supply chain, and information about use of this hazardous chemical may not be transmitted all the way back to the brand owner. Another brand owner commented that he does not think chemical manufacturers know how their products are being used farther downstream or in what final products they ultimately end up. He is not convinced that the hazards are understood for all chemicals in their final applications.

As related concern, a few downstream users said that even if they ask their suppliers for information about the chemicals contained in the supplied materials or components, there is no guarantee that the information provided is accurate. Companies were mixed in their opinions on whether testing of final products for certain chemicals is the best approach to verify information provided by suppliers. Some companies rely on testing, while others think it is a complex and costly procedure

Information can get lost between ODM and OEM

Another factor to take into account specifically for the electronics industry is the emergence of the Original Design Manufacturer (ODM) model. An ODM is a company which designs and manufactures a product which is specified and eventually branded by another firm for sale. ODMs have grown in size in recent years and many are now sufficient in size to handle production for multiple clients, often providing a large portion of overall production. A primary attribute of this business model is that the ODM owns and/or designs in-house the products that are branded by the buying firm. This is in contrast to a contract manufacturer, CM. This development can have an impact on the flow of information, as it can be lost between the ODM and the Original Equipment Manufacturer (OEM), or the ODM can choose to not forward all/parts of information due to resource or proprietary information issues. Given the size of ODMs they are increasingly have more power and OEMs often lack the power to demand information related to substances, as this is a cost/resource-intensive activity for the ODM.

Product developers and materials scientists are not trained in environment and safety

Product developers and materials scientists have historically been focused on performance, price and function. Information systems have developed around these three elements. Environmental performance and safety metrics are relatively new, and training/education has not kept pace with the demand for these new areas of knowledge. Currently, there are few universities that provide degrees related to the environmental performance of products, so product and material designers are typically not learning about environmental and safety aspects of design. Thus, lack of education in safety and environmental performance of products is a fundamental problem, and it will likely take some time to embed this new way of thinking in the supply chain.

Companies can give information to e-waste handlers in developing countries, but these handlers may not understand it or be able to use it

Companies can give information about chemical content to e-waste handlers in developing countries, but the handlers may not understand it or be able to use it. Even if these e-waste handlers know about the risks associated with their work in product disassembly and extraction of valuable materials, they may have no other work options and need the work to survive. Also, they may not have the resources to improve the ways they are currently handling e-waste.

More information on chemical uses and safer substitutes is needed

A few interviewees discussed information that could be helpful to downstream user companies. Two brand owners pointed out that many of the existing information systems used in the electronics industry fall short in two main ways. First, many of the lists of undesirable chemicals do not contain any indication of how the chemicals are used or in what types of products one might find them. For this reason, downstream users cannot easily use these lists to remove undesirable chemicals from their products. Second, the currently available lists do not provide recommendations for replacement chemicals or materials. Thus, the downstream user does not know if the chemicals or material they use as a replacement is any better than the original substance.