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LCD Television Recyclability and Human Recycling Behavior

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### Abstract

Consumers buy a lot of electronic devices, which almost all inherently have a short life before obsolescence. The problem I am presenting in this paper is the issue of the post-consumer life of these products and the implications therein. An attempt is made to generate a holistic view of the situation from materials used in manufacture, through consumer behaviors, to product post-life. Also presented are ideas that could help to attenuate negative factors by promoting recycling behavior, encouraging greener product design, encouraging proper e-waste handling and increasing government influence on these issues. The focus in this case is specifically on LCD televisions, one of the most popular kinds of consumer electronics.

## LCD Television Recyclability and Human Recycling Behavior

There are several factors that affect the useful lifespan before obsolescence of consumer electronics. Sometimes products are rendered obsolete by the emergence of new features in more current retail offerings, and other times the end of life is marked by hardware failure that renders the television useless. For the purposes of this paper, I will be focusing on the latter. Regardless of the kind of damage, in most cases the television is likely to be a total loss because the cost of repair services or new components can often be more than the cost of a new television. (Hempel, Busch, Hountz, Charles & Reneker, Laboratory Experiments, 2-17-2009) It simply makes financial sense for the consumer to discard the whole television and buy a new model.

In the current state of consumer culture in the United States, many consumers do not give much thought to where our wastes end up. The presence of recycling bins and recycling programs for materials like paper, plastic and glass have impacted the post-life of those materials, but destinations for obsolete consumer electronics are not as obvious. Leaving a television out on the curb with the trash is often the easiest option for the consumer. Even in cities with municipal recycling centers, it is not extremely common to find a facility to take consumer electronics without some cost involved. There is also the issue of transportation. Modern televisions are quite large making it impossible for consumers without automobiles to take them to recycling facilities. If such equipment is left on the curb and the city's waste management system does not reroute it to a recycling or processing facility, it is quite possible that it could end up in a dump or landfill, creating the potential for serious health concerns. If the television makes it to a recycling center, chances are good that at least some of its materials will be reused, but it is also highly possible that materials could wind up in a municipal incinerator.

For the best case scenario, companies in the emerging field of electronics waste processing will likely end up with the still in-tact product. The business model of these companies is important in considering what happens to the waste materials and understanding the actual cost of recycling. Our team visited a large scale electronics waste processing facility to get more information on the process. (Hempel, Busch, Hountz, Charles & Reneker, Processing Facility Visit, 4-16-2009) From the information we were given, processors of this type have two main revenue streams. The first is a fee collected from the consumer or business disposing of the electronics equipment. This idea of this fee appears to be to cover the cost of the processor to safely handle and process the materials into forms that they can sell and ensure that hazardous materials end up with appropriate handlers. The second revenue stream is the sale of commodities from the equipment they have taken in. These commodity sales could be something like the sale of sorted, shredded scrap steel to a steel smelter, or as simple as resale of functional equipment on the secondary market. Sending raw materials like steel, copper, glass and plastics to smelting companies who can process the scrap into usable materials for resale in industry is better for the environment, and creates a market for such processors to flourish. The secondary market sales seem like a good idea. The reuse of old equipment is always preferable to it winding up in the dump, but secondary market sales can sometimes have negative effects. The so-called secondary market may or may not include overseas export. The facility we visited screens their products to ensure that they are working, but there are other agencies that do not. Export sales of discarded electronics are currently being used by companies in many countries including the United States to circumvent the Basel convention, an international treaty designed to prevent the transfer of hazardous wastes to less developed countries. Such shipments are partially made up

of non-functional, non-repairable equipment which is sent to countries like Nigeria and Ghana as a means of disposal.

In an article titled “Inside the Digital Dump” published by the Basel Action Network (2007), information about such shipments and the movement of the items in them was documented in the port city of Lagos, Nigeria, as it appears to be fairly representative of cities in less developed countries receiving discarded electronic goods. It is important to mention that the BAN document focuses mostly on computer and cellular phone related items, but did include other electronics devices. That said, I still believe that this example is relevant as an example of common consumer electronics end of life destination. The number of imports to Lagos is staggering. According to the article, one warehouse manager in Lagos estimated that 500 shipping containers per month arrive full of electronics. He also estimated that each container contained about 800 computer monitors or CPU’s, adding up to around 400,000 pieces of electronics shipped in monthly. So many pieces of consumer electronics could really be a boon to burgeoning Nigerian electronics businesses. The problem is that most of what they receive is not usable or repairable. The Assistant General Secretary of the Computer and Allied Products Dealers Association of Nigeria, Mr. John Oboro, estimates that around 75% of the material imported is unusable and unrepairable, and is usually immediately dumped. Unlike the United States, Nigeria does not have companies focused on material reclamation for resale. Instead, almost all of their use of these items is based on repair. If it is not possible or cost prohibitive to repair, then it has no worth to them. These worthless items are generally discarded in local dumps, which are nothing more than unlined holes in the ground. It is apparently common for these dumps to be set on fire to reduce their volume. As stated above, LCD televisions are cost

prohibitive to repair in the event of bulb or panel failure, so any such televisions shipped to Lagos in this manner would likely end up in a dump.

That's only one side of the import story though. There is a rapidly growing electronics repair and resale industry in Lagos which likely could not be possible without such inexpensive shipments of electronics goods. The interesting twist in this is that if the companies sending shipments to Lagos were to spend the time to sort it and send only known-good items, the price would substantially go up. Most Nigerian buyers prefer to take their chances with the lower cost, unknown condition items.

It is important to understand why dumping of electronics waste into landfills is bad. It is commonly understood that it is "bad for the environment", but why. The biggest issue here is the idea of hazardous materials contaminating the environment and affecting the health of living things in that environment, including humans. LCD televisions specifically may contain several hazardous elements. Brominated flame retardants (BFRs) are one kind of potentially hazardous substance that we see in consumer electronics. Polybrominated diphenyl ethers (PBDEs) are a subgroup of BFRs, some variations of which are commonly used in the plastic housings and printed circuit boards of many consumer electronics devices. While the health effects of PBDEs in humans are not yet fully understood, existing research shows links to developmental issues in animals. There are 209 different kinds of PBDEs differentiated by arrangements of as many as 10 bromine atoms. PBDEs containing 5, 8 or 10 bromine atoms have been shown to cause brain development problems in mice and rats. (Webb 2007) Perhaps even more alarming is the fact that some BFRs like PBDEs may not remain bound to the plastic that they are embedded in (BFRs | the Issue), meaning that these molecules can be transferred through air, water and other means. PBDEs are bio-accumulating in animals (Herat, 2008) that have had exposure to them via

the previously mentioned transmission methods. The chemical actually builds up in the body in fatty tissue, blood and breast milk. As more and more products containing PBDEs enter the environment, we see the levels of PBDEs in humans rising rapidly. We can better understand the risks as presented by Herat (2008, p. 351):

Hites (2004) conducted a meta-analysis of concentration of PBDEs in the environment and people and found that total PBDE levels in human blood, milk and tissues have increased exponentially by a factor of around 100 during the last 30 years effectively doubling the levels every 5 years. This study also found that the increase in PBDE levels in the environment and human in North America to be much higher than in Europe. These findings were further confirmed by Schechter et al. (2005) where they found that the U.S. human breast milk and blood levels of PBDEs are presently the highest in the world. Although PBDEs have been detected in humans, there is lack of data on human health studies so far. However, studies on animals, reported in detail by Darnerud (2003), have shown effects on the nervous system, reproduction and development.

In addition to PBDEs contamination, BFRs can also release dioxins when burned or thermally stressed.

Poly vinyl chlorides (PVCs) are another potentially hazardous substance often used in consumer electronics. PVC based plastics are mainly found in casings and cable sheathings. However, they are also found in printed circuit boards, component capsules, and other components (PVC Products). As with BFRs, the problem with PVCs is that they produce dioxins when burned or thermally stressed. Dioxins can accumulate in the body, attaching to fat, and can be carried in breast milk from mother to child. Research has shown that dioxin exposure

has negative effects on the health of rhesus monkeys as well as human children, including nervous system development issues. (McRandle, 2006)

One of the more obvious health concerns with electronics waste is exposure to heavy metals. LCD televisions can contain several toxic heavy metals, two of the more prevalent being lead and cadmium. Lead can be found in some solders as well as in some PVCs as a stabilizer. Lead can accumulate in the human body and high levels from repeated exposure can cause irreversible effects on the nervous system. Similar to lead, cadmium can be found in some solder joints and switches as well as in some PVCs as a stabilizer. Cadmium is known as a human carcinogen and can cause damage to the kidneys and bone structure through long term exposure. (Zheng et al., 2008)

Steps have already been taken to try and prohibit the use of materials like these from consumer products. The European Union created the Restriction of Hazardous Substances (RoHS) directive to ban products containing these substances from sale in the EU. RoHS specifically addresses lead, cadmium, mercury, hexavalent chromium, Polybrominated biphenyls (PBBs) and PBDEs. While the RoHS directive bans the use of these substances, it does provide some exceptions for their limited use. The United States is not subject to the RoHS criteria, but many US manufacturers comply with it in order to sell their products in the EU. In the US, an organization called EPEAT has created the IEEE 1680 standard whose intent is similar to that of RoHS, except it is not governmentally mandated. EPEAT goes a step further and offers a rating system for quantifying levels of compliance with their directive.

In understanding that the ultimate problem with consumer electronics is a high volume of potentially toxic wastes entering the environment and affecting the health of many living things,

the goal should be to find ways to limit the amount of wastes that get to the environment. There are a few ways to address this. The best method might be to encourage manufactures to limit or even discontinue use of toxic chemicals in their products. Another method could be ensuring that products containing these materials are correctly processed and recycled when their lifecycle ends.

In the example of manufacturers including less potentially toxic chemicals in their products, governmental or consumer pressure would be required to convince them to alter their designs and processes since making these changes would have a financial cost. If the federal government were to enforce a standard like ROHS or EPEAT's IEEE 1680, it would likely help. Consumer input could also play a factor in getting manufacturers to comply or exceed such standards. If consumers refuse to buy an environmentally dangerous television, the manufacturers would have no choice but to clean up their products. Getting electronics consumers to demand a more "green" television requires an examination of consumer purchasing behavior.

Many factors play a role in determining why a consumer chooses one product over another. Here I will investigate a few possibilities that may have relevance in increasing awareness of the issue of hazardous materials in consumer electronics as well as marketing "green-ness" as a desirable product trait. One such element that affects consumer purchasing choices is the idea of brand. When a brand takes on human characteristics it can play a larger role in the life of the consumer. The relationship between brand and consumer can help the consumer to project traits about his self to others or also help him to realize a desired self-concept. (Swaminathan, Stilley & Ahluwalia, 2009) The obvious application of this idea is that a person who cares about the environment or recycling is likely to choose a brand that is

environmentally friendly, although I think there is a less obvious application. In the paper cited above, an anxiety dimension and avoidance dimension were noted as factors in a consumer's attachment to particular brands. The anxiety dimension represents the level of a person's perceived self worth. A person with a high anxiety dimension is usually more dependent on social approval, and may have a low perceived self-worth. Purchases made by a high anxiety dimension individual are likely to be influenced by the ideal self-image that they feel they are not achieving or by the idea that others might be impressed with their choice. On the other hand, a person with a high avoidance dimension is likely to be less concerned what others think, and is more apt to purchase brands that have an exciting image, since it's personally stimulating. This information useful in consumer targeting both for marketing of green products as well as targeting audiences in publicity about environmental issues regarding consumer electronics. A high anxiety dimension consumer might be likely to buy a product that is publicly touted as environmentally friendly if it is assumed that others in his or her social group would view this positively. Such a purchase could also contribute to the person's achievement of their ideal-self, which would likely give them positive reinforcement to buy greener products in the future. Similarly, environmentally friendly products could be marketed with an exciting image to help attract the high avoidance dimension consumer who might not be concerned about the environmental impact of their purchases. In either example, I believe that the fact that consumers identify with the perceived human elements of brands is important in the agenda of selling greener products.

Another article regarding consumer choices with regards to brands uses the idea of Terror Management Theory to describe why consumers make choices based on brand, arguing that materialistic individuals form strong connections to their brands as a means of assuaging

existential insecurity. The idea is that most people are afraid of death, and they are symbolically able to cope with death anxiety through self and communal brand identification (Rindfleisch, Burroughs, & Wong, 2009). If death anxiety is such an issue with so many consumers, then surely knowing that some products may threaten the length of their life would influence purchasing decisions. Choosing a brand associated with green-ness might also contribute to a feeling of community inclusion as the threat of toxic materials is global, and also because the number of people who are joining environmental awareness groups is growing, whether it be an organized group like Greenpeace, or an ad hoc group on a social networking site.

Another factor that affects consumer purchasing choices is the idea of specification seeking. A paper titled *Specification Seeking: How Product Specifications Influence Consumer Preference* (Hsee, Yang, Gu, & Chen, 2009) presents the idea that consumers rely on quantitative specifications for purchase related decision making when the specification is something that they cannot directly experience. The article also makes the distinction between fundamental and proxy attributes:

A fundamental attribute refers to an objective with which the decision maker is concerned, and a proxy attribute is an indirect and imperfect measure of the fundamental attribute. (p. 935)

A common example of this might be the number of megapixels in a digital camera. The average consumer likely cannot tell the difference in photo quality between 5 and 6 megapixel cameras, but given the choice between the two at the same price, they would likely choose the higher number. To bring this example into the context of consumer electronics and e-waste, the fundamental attribute might be measurable amounts of hazardous materials, or quantification of

exactly how hazardous the materials are. Stating the amounts or extent of hazardous material could be quite complicated, could likely be spun in several different ways, and would probably end up being difficult for the consumer to understand. A proxy attribute could be assigned as a standardized way of taking the hazardous material content into consideration and putting it into a simple number or rating scale for sake of easy comparison. I think this idea is especially relevant since there are existing rating systems like EPEAT. If more products carried an EPEAT certification level badge and consumers were educated about what EPEAT's certification is, it could likely be a motivator for selection of the most compliant products.

In addition to consumer preference impacting manufacturer's designs, government legislation could also play a role. The RoHS directive is an excellent example of successful use of such a government mandate. Short of completely banning use of hazardous materials, it is possible that local or federal governments could allow tax breaks for companies who meet or exceed green-ness certifications, similar to those offered by some states for businesses meeting the requirements of the Leadership in Energy and Environmental Design (LEED) Green Building Rating System. Ultimately, someone will have to pay for the handling and recycling of hazardous materials and the mitigation of their effects on the environment. It only makes sense to spend this money as an incentive to prevent their use before they can possibly cause any damage.

The other half of keeping hazardous electronics waste materials out of the environment is the post-consumer element. Since it seems that electronics devices will not be 100% free of hazardous materials anytime soon, it is important that the products reach a facility where they will be recycled properly. In order to promote recycling, we first must understand the behavioral aspect of it. In overlapping information on recycling behavior from several studies, There are four main issues that seem to play a marked role in a consumer's recycling behavior – Attitude,

Affect, Subjective norms, and Past behavior. Attitude is a somewhat nebulous trait; how the person generally views the idea of recycling. Attitude appears to be the component most readily open to influence and also seems to have the most influence on actual behavior. Research regarding the effect of attitudes on recycling behavior generally recognizes two levels of attitude, weak and strong, which are measures of how favorable pro-environmental or recycling ideas are to the individual (Schultz & Oskamp, 1996). I think it is important to take into account which of these two attitude strength classifications the target audience falls into when crafting pro-recycling messages.

Affect is a person's emotional feeling towards an issue. A paper by Biwas, Licata & McKee (2000) discusses two different ideas regarding ways that affect can influence behavior. The first posits affect is foundational in developing attitudes and thus effects behavior through them. Another hypothesis suggests that affect can directly influence behavior. This might be particularly applicable in cases where there is a lack of a strong attitude. In either case, emotional appeals seem to have a definite effect on behaviors, and such appeals can certainly be used in the promotion of recycling behaviors.

Subjective norms are the de facto behaviors of the persons peer group, or the consumer's perception of what peers think about a behavior. (Biwas, Licata & McKee, 2000) Like peer pressure in general, subjective norms can be strong factors in a person's behavior. This has impacts in both positive and negative ways, encouraging behavior that peers participate in and approve of, and discouraging behavior that they do not. Further, it is suggested that a part of the strength of subjective norms is that people are generally aware that non-compliance with them will cause consequences, whether it be shunning by the peer group or understanding that not recycling will cause harm to the environment.

Past behavior is a person's past experience with recycling or lack thereof. Results show that past recycling behavior has twice the influence of attitudes on intentions to recycle (Knussen & Yule, 2008). It is also worth noting that the relationship between intention and behavior is not static, meaning that sometimes those with the intent to recycle do not actually do it. Lack of habit has been shown to significantly affect a person's intentions with regards to recycling whether or not they have recycled in the past. Still, past recycling behaviors do have some impact on reducing the effect of lack of habit on recycling behavior. In a practical application of this concept, we could say that an incentive for recycling might cause someone to adopt the behavior in the short term, but the incentive would have to continue long enough to be habit forming in order to see a sustained behavior over time. Another important factor is that habit forming is much more difficult when the process may have steps separated by large spans of time. Reinforcing each step of the process separately can help, for example each time a person starts to throw a can in the garbage, and they remember to rinse it and put it in the recycling bin instead. Then they would need to remember to take the recycling out with the trash. The repetition of this series would help create habitual behavior patterns. This idea also shows us a difficulty with recycling consumer electronics – it's not all that often that we dispose of a television. This could make it difficult to create habitual behavior (Knussen & Yule, 2008).

In addition to these four variables, I also think that the issues of situational constraints and effort required to recycle can play an important role in recycling behavior. Situational constraints in this case are anything that prevents a person from recycling. Earlier in this paper I mentioned the situational constraint of a person trying to properly dispose of a LCD television without owning an automobile. They simply don't have the means to transport it to the recycling center. Similarly, curbside recycling may not be available in some rural areas preventing people

there from recycling. It may seem like a given, but accessibility of recycling programs is really the largest factor in getting consumers to recycle. I personally think that non-traditional means should be considered for enabling those with situational constraints to participate. Examples of this might be a pick-up service for urban consumers with large electronics items to dispose of, or an annual outreach for rural consumers. Effort has also been shown to be a moderator of attitude, which has an impact on behavior. Not surprisingly, it has been observed that individuals with a strong favorable attitude towards recycling are more likely to participate in recycling activities that require more effort than individuals with weak favorable attitude. It was also found that incentives such as money were more likely to increase the amount of effort an individual with weak favorable attitude would make to recycle than it would for the strong favorable individuals. (Schultz & Oskamp, 1996) In understanding the effect of effort on recycling behavior, I think it is possible to use this knowledge to help improve consumer recycling in general. Targeting individuals with weak favorable attitude and providing them with enough incentive to get them to participate in recycling activities for a long enough period of time to establish habitual behavior seems like a great place to start.

With the information I have presented here, I think a good case is made that the biggest problems with the recyclability or “greenness” of LCD televisions and other consumer electronics are the potential consumer exposure to hazardous materials like unbound BFRs, as well as the more long term concern of appropriate handling and reclamation of these waste materials, whether they be hazardous or not. The burden of responsibility in these issues falls on both the electronics manufacturers to design their products to be less toxic, and easier to recycle, and on the consumer to ensure that their post-life electronics get to an appropriate handling center. Government involvement in both sides of the issue could help tremendously as well.

Impacts on the manufacturer side of things could be achieved by some combination of consumer pressure for greener products, which could be facilitated by purchase power using a greenness rating system as a criteria for consumer preference or it might also be achieved by government incentives for compliance. The consumer recycling element could be best achieved by informing consumers of both the consequences of non-compliance with recycling behavior which may change their affect towards recycling which will impact their attitude and hopefully behavior. In addition, it would be beneficial to inform them about how they can participate in recycling. I also believe that community outreach projects with participation incentives could help establish habitual recycling behavior for both groups with and without situational constraints such as recycling program availability in their areas. I think the government could also step up in the post consumer element of electronics waste as well. Monitoring the export of these materials would help to ensure that unusable equipment goes to a proper recycling center and not overseas where it would likely be dumped and burned.

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