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The Capacity of the electronics industry for closing the lifecycle look: Assessing the infrastructure for the recovery and recycling of electronics in the United States

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THE CAPABILITY OF THE ELECTRONICS INDUSTRY FOR CLOSING THE LIFECYCLE LOOP:

Assessing the Infrastructure for the Recovery and Recycling of Electronics in the United States

By

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ABSTRACT

This work examined why the electronics industry, specifically producers of commercial and consumer equipment, does not complete the product lifecycle by recapturing valuable materials from products when the products reach the end of their useful life. The electronics industry, it seems, is not capable of fully recovering and recycling its products. It lacks the infrastructure, or the underlying foundation, to enable the industry to take back its products and recycle or reuse the components that make up those products. This research identified and examined the various infrastructure deficiencies, including technical and regulatory factors, causing the recovery and recycling of electronic products to remain infeasible. This research provided a summary of the initiatives that are currently taking place to help establish an infrastructure in the U.S.

All information is current as of May 2001.
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I. Introduction

According to the Electrical and Electronics Group of the American Plastics Council, numerous businesses, states, counties, and municipalities have begun asking a common question, “What is the best way to manage electronics from households and businesses once they are no longer in use?” In the past, and even today, electronic equipment is either landfilled, incinerated, or disassembled to extract only the precious metals. Presently, questions are being asked about these practices and whether they are the best economic and environmental practices. (Plastics from Residential 1)

Electronics from households and businesses typically fall into the “consumer equipment” or the “commercial equipment” categories within the electronics industry. The International Association of Electronics Recyclers (IAER) defines electronic equipment as “a product or apparatus that has its primary functions provided by electronics circuitry and components.” Examples include semiconductor devices, electro-optical components such as cathode ray tubes, and electronics packaging such as printed circuit boards and connectors. (Electronics Equipment 1)

These electronic products are being improved and updated so rapidly and the pace of technological change is ever increasing causing waste from the electronics industry to grow at an advanced pace. The U.S. Environmental
Protection Agency (EPA) estimates that electronics waste accounts for about 1% of the United States’ 210 million tons of solid waste each year. Additionally, the EPA cites European studies that estimate the volume of electronics waste in Europe, including old TVs, PCs, printers and other aging high-tech scrap, is growing 3% to 5% a year. This is almost three times faster than the overall municipal waste stream in Europe which is estimated to be growing at 1% to 2% a year. (Arensman 1)

This growth in the amount of electronic waste is promoted by the pace of technological change, mostly due to the decreasing cost of electronic chips for electronic products. This, in turn, allows for an ever-increasing number of new products with ever-shorter lifespans. In 1965, a physical chemist named Gordon Moore, working with the Fairchild Semiconductor company, predicted the number of math-crunching transistors that computer engineers could cram onto a chip would double every 18 months. This comment was later termed as “Moore’s Law”. (Yaukey 1)

Moore’s Law is evidenced by the decreasing life span of a personal computer. A study performed by the National Safety Council (NSC) found the average lifespan of a personal computer in 1992 was 4.5 years. In 2005, the lifespan will be just 2 years. 350 million computers will have reached obsolescence, with at least 55 million expected to end up in landfills. (Yaukey 1) “We have more
planned obsolescence than at any other time in history," says Ted Smith, executive director of the Silicon Valley Toxics Coalition, an electronics recycling advocacy group. With all of this obsolescence, very little electronics waste is actually being recycled. The NSC reported that only 11% of discarded computers were recycled in 1998, compared with about 28% of overall municipal solid waste. (Arensman 1)
II. Proposed Work

A. Statement of the problem

This paper will identify the barriers that are preventing a recovery, reuse and recycling infrastructure from being established, and how, in some cases, those barriers are currently being overcome. The anticipated outcome will be to identify the problem: why electronic products are not being recovered, reused or recycled. The paper will also provide a summary of the first steps being taken to solve the problem: initiatives that are currently taking place to help establish an infrastructure in the U.S.

B. Hypotheses

- Not enough waste material from the electronics industry is being recovered, reused or recycled because the supporting infrastructure within the U.S. electronics industry is immature or non-existent.
- The electronics industry as a whole does not have a means of collecting waste and finding an outlet for that waste in the U.S.
- An infrastructure needs to be established in the U.S. to enable waste to be shared, reused, and recycled within the industry.
C. Limitations of the work

Electronics producers tend to not acknowledge that there is a problem with the recycling and reuse of their products. Thus, they may not be interested in discussing the problem or any potential solutions. Additionally, many are not willing to invest the needed resources to make any changes.

This paper will not cover the recycling of plastic from electronics products in depth. Much literature exists on this topic but I am choosing to not include it since it is a widely covered topic with lots of interest already captured.

D. Methodology

The methods used to research this topic included a review of relevant literature and in-depth interviews. It was determined that enough information was collected when resources were fully utilized, literature reviews became repetitive and responses to questions revealed no further substantial information.

1. Review of Relevant Literature

A thorough review of relevant literature, including websites, books, magazines, and journals, identified categories and themes. These categories and themes include environmental impacts of electronic products disposal, current problems and difficulties with recycling, foreign country initiatives including the European

Major categories of literature review included:

- **Introduction**
  
  The literature reviewed for this section helped to build the introduction for the paper. The background described the electronics industry, the lifecycle process and the requirements for an infrastructure.

- **Statistics**
  
  The literature review for this section helped to describe the problem. Specifically, the statistics helped to establish the need for this work including the rapid increase of electronics waste, current reuse and recycling statistics and industry obsolescence.

- **Environmental Impacts**
  
  This review helped to establish this research as important and timely.

- **Current Problems with Recycling**
  
  This review helped to establish the lack of infrastructure and why it is difficult to develop and establish.
Foreign Country Initiatives

Europe and other countries have been able to move forward with electronics recycling and lifecycle closure. This includes recycling programs and government or regulatory actions.

Government Involvement / Enacted or Proposed Regulations

Reviewed literature included the regulations or proposals presented in the United States for product recovery, reuse, recycling and material or design changes.

Conceptualized Solutions

Reviewed literature revealed municipalities, organizations and businesses have been trying to find the successful aspects and requirements necessary to establish an industry-wide infrastructure.

This literature review prepared the researcher for conducting in-depth interviews.

2. In-Depth Interviews

In-depth interviews were conducted in-person with those knowledgeable about or working in the electronics industry. Interviews with others working in the recovery and recycling industry, specifically electronics, were completed. Those interviewed discussed why the infrastructure is immature and why finding a
resolution to eliminating electronics waste has been a slow evolution. The interviewees' valued opinions and experience helped determine the problems with recovery and recycling and the reasons behind the incomplete lifecycle of the electronics industry.

Interviewees were limited to those located in the U.S. and to those which have experience with electronic products. Interviewees were selected from industry, academia, and electronics recycling services.

**Interviewees**

The following individuals were interviewed:

1. Jack Azar, Vice President, Environment, Health & Safety, Xerox Corporation

2. Dr. Nabil Nasr, Director of the National Center for Remanufacturing and Resource Recovery at Rochester Institute of Technology’s Center for Integrated Manufacturing Studies

3. Dennis Zink, Integrated Recycling Services Co., LLC. Mr. Zinc is responsible for finding reuse and recycling opportunities for waste materials from Xerox Corporation’s Monroe County, NY facilities and has had experience with the Eastman Kodak Company's recycling programs.
4. Conference call With EIA (Electronic Industries Alliance) on possible industry end-of-life program for electronics. “A small workgroup of EIA’s Environmental Issues Council held a conference call the week of January 10, 2001 to discuss whether the industry should develop an industry-wide program to advance the recycling and reuse of used electronics. EIA unveiled its Consumer Education Initiative (CEI) on January 31. The CEI is an Internet site that will link consumers with reuse and recycling opportunities for their used electronics. The industry is deciding whether other responses are necessary to counteract growing pressure from state and local governments that manufacturers must do more than provide recycling and reuse information.”

Attempted Interviewees

Interviews with government agencies and electronics industry support organizations was attempted but not accomplished due to scheduling, inaccessibility, and time constraints.

1. Waste Management, Syracuse, NY

2. Holly Evans, Staff Director & Deputy General Counsel, Electronic Industries Alliance
3. Diana Bendz, IBM's Director of Environmentally Conscious Products

4. A representative from EPA's Extended Product Responsibility or Waste Wise programs

Interview Content and Questions

The interviews consisted of questions and discussions involving the current practices, the direction the industry would like to take, the inhibitors to recovery / reuse / recycling, changes that need to be made, enablers of change, and the ideal infrastructure.

1. When you think of the “electronics industry”, what types of equipment and products do you think are produced?

2. Can you name some companies that you think are in the “electronics industry”?

NOTE: These questions verified that there was consistency among the interviewees’ understanding of what is meant by the term “electronics industry”.

3. Technology is moving at such a rapid pace. Computers are now becoming obsolete in about 2 years. What do you suggest should be done in order to
reduce disposing of (e.g., landfilling) new electronic products, such as computers, after only 2 years?

NOTE: This question attempted to get the interviewee thinking generically about the problem and obsolescence.

4. Can you describe alternatives to discarding products other than landfilling?

NOTE: This question attempted to generate discussion of alternatives to landfilling such as reuse and recycling and take-back programs.

5. What do you think is preventing companies from reducing the materials they use?

NOTE: This question and the next several questions begin thoughtful discussion about obstacles that exist to reducing, reusing and recycling by electronics companies.

6. If some companies are not using recycled materials, what do you think is preventing them from using recycled materials?

7. Some companies do reuse or remanufacture some parts. However, not all parts are reused. What do you think is preventing companies from reusing more materials?
8. Would you like to see the manufacturer of a product design the product differently so that it would not be landfilled? Why or why not?

9. How would you redesign the product so that you could obtain more value from it?

NOTE: These questions begin to take the issue to a personal level and seeks to determine level of commitment.

10. What would provide incentive for a company to reduce material usage, reuse parts and recycle their products?

NOTE: This question and the next several attempted to generate discussion of external incentives or motivators, initiated from the government, that would encourage reduction, reuse and recycling of products and their components.

11. Would you agree or disagree with the government requiring a certain percentage of a product be reusable? Recyclable?

12. Would you agree or disagree with the government requiring a certain percent of the product’s materials be reduced?
13. If the government does not create laws requiring increased reusability, or recyclability, do you think a manufacturer would change the design of a product to make it reusable or recyclable? Why or why not?

14. If the electronics industry had an established “infrastructure” for reducing, reusing and recycling materials, describe what that infrastructure would look like.

NOTE: This question is intended to get the interviewee thinking generically about the overall system.

15. How would you suggest creating or establishing this infrastructure that you described?

NOTE: This question and the next several questions probe for more specific detail.

16. What aspects of your infrastructure already exist?

17. What are the obstacles to developing this infrastructure?

18. How could these obstacles be overcome?

19. Is financial commitment one of the obstacles? Why or why not?
20. In your opinion, what needs to change in order for reusing and recycling of products to be more profitable?

21. How would you persuade a company’s management to make the initial investments necessary to support the development of an infrastructure?

22. Could different companies in the electronics industry come together to create the infrastructure that you described? If so, how?

23. Do you think that there would be competition or teamwork?

24. What is the likelihood that you or your customers would use a product that has been recycled or reused using post-consumer parts?

NOTE: This question and the next several questions probe customer behavior as a factor influencing the viability of the infrastructure.

25. If a product contained recycled and reused parts, but the price was now higher, would you or your customers still buy that product just because it is environmentally friendly?
26. If the reused parts were tested and certified to perform the same as new parts, would your answer change? Why / why not?

27. If the product met your functional requirements and cost 10% less than a “new” product, would you be more inclined to purchase it? Why / why not?

28. What would encourage you to purchase a product with reused components?

29. Some companies may argue that it would cost too much to change the industry in order to meet reuse/recyclability needs. If they were forced to change, they argue that the price of their products would increase. Would you be less likely to buy their product? Explain.

30. Companies may argue that most customers are not concerned with the level of “environmental friendliness”. What do you think?

Follow-up Questions

1. Is there anything else you would like to share or think that I should look into further?

2. Can you think of any other resources that would assist with this research?
3. Can you recommend others knowledgeable in this topic that I should contact?

4. Can I mention that you gave me his or her name?

**E. Analysis and Evaluation**

The information collected during the interviews was summarized and categorized. It was anticipated that the responses would fall into the categories similar to that which the literature review had been categorized. Trends, similarities, commonalities, differences, and uniqueness were sought. Once compared to the literature review, each common subject matter gained additional support. For those topics that were outliers, each was evaluated for its relevance and determined if it should be pursued or eliminated from the research.

The problem, “why electronic products are not being recovered, reused, or recycled” has been identified and the findings summarized. Electronic products are not being recovered, reused, or recycled due to obsolescence, wasted resources and the presence of toxic substances. Nearly every source, for example, the Electrical and Electronics Group of the American Plastics Council (APC), the Environmental Protection Agency (EPA), the International Association of Electronics Recyclers (IAER), the National Safety Council (NSC), the Silicon Valley Toxics Coalition, Dr. Nabil Nasr of RIT, Dr. Jack Azar of Xerox, and Mr.
Dennis Zinc of Integrated Recycling, agreed that obsolescence and rapid change in technology are significant contributors to the inability of the electronics industry to recover, reuse and recycle its products. With the increase in electronics waste, the EPA and Dr. Nasr agreed that resources such as metals, plastics, glass and other materials were being wasted and not used for their intended life span. The EPA, state and local governments are concerned with the potentially toxic materials not being disposed of properly resulting in releases to the air, land and groundwater.

Recycling capabilities are lacking as was identified by IAER, NSC, APC, Sony and Hennepin County Minnesota, the EPA, Hewlett Packard and IBM. It remains cheaper to landfill, incinerate or smelt waste. The findings reveled that major sources of recycling are the electronics manufacturers themselves. This was supported by Dr. Azar, Dr. Nasr, Mr. Zinc and research performed by many organizations. However, the barrier to recycling is with other businesses, municipalities and individuals not having the capability of collecting, disassembling and recycling equipment. Therefore, the research does not include the detailed efforts of manufacturers. If this capability were established then the recycling efforts of the electronics manufacturers would be supported, possibly expanding the life of the product materials and overcoming obsolescence.
The findings were also analyzed to determine what steps were being taken to solve the problem, specifically, initiatives taking place to establish an infrastructure in the U.S. The initiatives identified include Product Lifecycle Assessment and Management, Extended Producer Responsibility, Infrastructure Establishment, and Non-U.S. Initiatives. Additionally there are several U.S. initiatives including those from the government, communities and interest groups, and recycling projects such as those in San Francisco, Minnesota and IBM’s takeback program.

Researchers such as Boswell, Weston, Fishbein and Stanford University, posed the best arguments for requiring a lifecycle assessment. After analyzing other arguments, the findings demonstrated that they had a sound argument for conducting a lifecycle assessment as the first step towards solving the problem of electronic products not being recovered, reused, or recycled. It would be difficult to understand why a product is not getting recycled if the life of the product is not understood.

Once the lifecycle is understood, the next step to solving the problem is to close the loop for material usage by practicing extended producer responsibility. Research did not reveal other strategies suggesting the producer was responsible for the lifecycle of the product, even after customer use. It was found that this strategy was the next logical step to solving the problem.
Many sources were consulted to develop the suggested infrastructure establishment for solving the problem of electronic products not being recovered, reused, or recycled. Several sources had many steps to their suggested infrastructures. When looking at all of the recommendations, it was concluded that there were similarities resulting in common basic steps to each recommendation with other ancillary steps provided for support of the infrastructure. These ancillary steps were removed and the basic aspects remained as the final suggested infrastructure. These basic aspects were substantiated by several initiatives taking place around the world.

The hypotheses were tested by conducting a literature review and interviews with professionals familiar with the electronics industry.

The hypothesis, “not enough waste material from the electronics industry is being recovered, reused or recycled because the supporting infrastructure within the U.S. electronics industry is immature or non-existent” was tested by consulting several sources capable of confirming that an infrastructure does not exist in the U.S. Additionally, the sources confirmed that it was the lack of this infrastructure that used electronics materials were not being recovered for subsequent reuse and recycling.
The hypothesis, “the electronics industry as a whole does not have a means of collecting waste and finding an outlet for that waste in the U.S.” was tested by researching the electronics industry and interviewing Dr. Azar and Mr. Zinc. It was found that some individual companies have established a collection/returns program for specific materials that the company itself can reuse or recycle. The research showed that no electronics companies have partnered together successfully to develop an infrastructure for the industry.

The hypothesis, “an infrastructure needs to be established in the U.S. to enable waste to be shared, reused, and recycled within the industry” was tested by researching efforts in countries other than the U.S. and by investigating efforts of municipality-company partnerships such as Sony in Minnesota. Other research was collected from organizations that have conducted pilot studies or surveys of those in industry, government and other support organizations.
III. Findings

A. Description of the Problem:

1. Obsolescence, Wasted Resources and Toxic Substances

The increase of electronics waste, along with the lack of reuse and recycling, raises great concerns. According to the EPA’s “WasteWise Update”, used electronics are a concern for the following summarized reasons:

**Obsolescence.** Technological advances are rendering formerly cutting-edge electronics obsolete.

**Wasted resources.** Electronics products are made of valuable resources, including precious and other metals, engineered plastics, glass and other materials, all of which require energy to extract and manufacture. Many electronic products also contain parts that could be profitably refurbished and reused with little effort. When we throw away old electronic equipment, we are throwing away these resources and generating additional pollution associated with the need to access virgin materials and manufacture new products.

**Hazardous and toxic substances.** Electronic products, notably those with cathode ray tubes, circuit boards, and batteries, could contain a variety of toxic
substances that may cause them to test hazardous under federal law and escape into the air or groundwater if disposal is not handled properly. According to the EPA, electronics waste is the single largest contributor of heavy metals (aside from automotive lead-acid batteries) to the U.S. waste stream. Examples of those toxic substances are:

- lead, used for radiation shielding in the glass screens (cathode ray tubes (CRTs)), and for solder; CRTs in computer monitors and televisions, can contain as much as 27 percent lead.
- cadmium, used in batteries;
- antimony, used as a flame retardant, chip encapsulant and as a melting agent in CRT glass;
- beryllium, used in connectors in cell phones and on older PCs;
- chromium, used in metal plating operations;
- mercury, used in very small amounts in the bulbs that light flat-screen displays. (Arensman 1)

There is some concern at the state and local levels that products containing these constituents might pose some environmental risks if they are not properly managed at end-of-life including landfilling, incinerating, and smelting. (Why Are Used 1)
Technology is moving at such a rapid pace which is evidenced by computers becoming obsolete in just two years. Dr. Nabil Nasr, Director of the National Center for Remanufacturing and Resource Recovery at Rochester Institute of Technology, states that computers and other electronics are not being used by the consumer for the full intended life of the product. A product is only used for a fraction of its whole lifecycle due to the changes in technology thus rendering it obsolete.

Nasr also states that companies are not reusing or remanufacturing parts to expand the lifecycle because of current market dynamics. The small volume of products that are currently collected do not make reuse, recycling or remanufacturing viable options for many companies. Over all, the U.S. consumes a variety of products that contain different sizes of components and parts which make the collection and sorting process uneconomical.

2. Recycling Capabilities

For a variety of technical and regulatory reasons it remains cheaper to simply landfill, incinerate or smelt the waste as opposed to collecting, disassembling and recycling the equipment. The International Association of Electronics Recyclers (IAER) states, “Electronics recycling is an emerging industry that is at a critical point in its development in terms of growth and challenges. As the production and use of electronics products continues to increase dramatically throughout
both the business and public sectors, the challenges of disposal and recovery of materials are becoming significant. Tens of millions of consumer electronics products, such as computers and televisions, are purchased each year in the United States. Recent studies found that over 70% of such products are currently disposed of in landfills. The number of personal computers available for recycling has been increasing significantly and is expected to reach 60 million units a year within the next five years.

The major sources of electronics products for recycling have been manufacturers and large users. In 1998, the National Safety Council’s Environmental Health Center found approximately 9.7 million units (or 275 million pounds) of electronic equipment were recycled in the US. More than 75% of those units came from original equipment manufacturers such as IBM, Hewlett Packard, Xerox, and other large-scale users in the commercial sector. Only a small portion, less than 3%, came from individual consumers. (Plastics from Residential 1) The volume of consumer electronics products being recycled, such as TVs, has not been significant. However, the inventory in the field is very significant (e.g., approximately 200 million TV sets). “A key element is the development of an effective and efficient infrastructure for the industry to utilize for managing the lifecycle of electronics products.” IAER feels that one area in particular is important to the future of the industry - that is the support and promotion of high
standards of environmental quality and regulatory compliance. (About Electronics Recycling 1)

The American Plastics Council (APC) states that little information exists, however, on recycling electronic equipment. It is not well documented what quantities of equipment are available, what types of equipment are found in which waste streams, what materials the equipment is made with, what technologies exist for material recovery, and what value materials might have once the product is disassembled and separated. The information that does exist is difficult to interpret. The types of collection programs, program timelines, and data tracking methods make it difficult to compare data and draw meaningful conclusions. (Plastics from Residential 1)

A recent report, “Plastics from Residential Electronics Recycling Report 2000” by the Electrical and Electronics Group of the American Plastics Council, uses a combination of data from APC, data from other sources, and case studies from Hennepin County, Minnesota, and San Francisco, California, to try to answer such basic questions as:

- What items are included in the definition of electronic equipment?
- What types and quantities of electronics are present in the waste stream?
- What materials are these items made with?
- Why are plastics used in their manufacture?
- What types and quantities of plastics are available upon recovery?
- What contaminants are present?
- What products can be manufactured with plastics recovered from end-of-life electronics?

APC hopes that by answering these questions, businesses, states, counties, and municipalities will have more complete information with which to make decisions about if and when recycling electronic equipment is an effective waste management option. While these questions are aimed at plastics, the same questions can be asked for the entire waste stream in order to gain information.

(Electrical and Electronics Group of the American Plastics Council, 1)

Consumers of electronic products pose the greatest problem for proper disposal. The EPA does not regulate residential computer disposal which means all of the toxic chemicals contained within the product can go with residential trash and off to a landfill. Regulators say most of the problem with consumers is timing and knowledge. Donating a computer is an option as long as it is not out of date. If a consumer is not able to donate it then recycling is the next option. However, Steve Rowe, a Washington state-based attorney specializing in environmental law and policy states, “As a rule, anytime the consumer has to look hard for a
means of disposal, they’re going to give up and (indiscriminately) throw out whatever they’re trying to get rid of.” (Yaukey 1)

APC has conducted a number of research projects and has summarized what they have learned about the end-of-life electronic equipment and what recycling might entail in a report from 2000. APC found that the items in the residential waste stream tend to be older products. Hennepin County Minnesota has been collecting electronic equipment from the residential sector for a number of years and estimates that televisions are typically between 20 and 25 years old and its computers are between 10 and 15 years old. The APC states that these older items are not good candidates for reuse since they contain more diverse materials than those found in current products. Newer products use fewer types of materials. When disassembling products that are 10 to 20 years old, it is more difficult to identify the materials from older products due to their age and diversity. These older materials are, therefore, not reused but rather disposed of. (Plastics from Residential 1)

In an EPA study conducted between 1997 and 1998, they found that nearly half of the material recovered from a residential collection program for electronic equipment was metal, one-third was plastic, CRTs (mostly glass) comprised another 12%. Wood comprised 5% of the material collected and the remaining 1% was other material. These categories were then broken down further with 23
separate commodities identified that had recyclable potential. Of the metals collected, only 50% of them are “scrap” metal with an existing and available recycling infrastructure. The other half of the metals was comprised of 11 different categories of metal with very low volumes of each. These comparatively low volumes make it difficult to recycle these metals and market them. Plastics have similar problems. If the plastic material can be identified, separated, and is available in significant quantities then there exists a chance that the plastic can be recycled and marketed. However, nearly 75% of the plastic collected is usually not homogenous plastic or it is contaminated with paints or other materials. (Plastics from Residential 1)

APC learned several important lessons from the characterization of Hennepin County’s residential collection of electronic equipment.

- There is a need for better sorting methods at a demanufacturing facility, especially if recycling programs are going to move toward economic sustainability.
- Storage and transportation are costly for recycling programs and programs cannot afford to store and ship parts that are going to be rejects.
- There is a need to develop better identification and separation equipment, especially for plastics.
- In order for consumer electronics recycling to approach feasibility, residential programs need to aggressively target computers and other electronic
equipment so that a rich source of high value materials can be collected and effectively recycled.

- Many of the electronic products currently in the residential waste stream were not designed for recycling because they were manufactured 20 to 25 years ago. These wastes require more complex processing systems to derive usable materials.
- Manufacturers of electronic equipment can work to better design electronic products for recycling such as reducing multiple use of metalized coatings, paint, labels and lamination. (Plastics from Residential 1)

Contamination of the waste stream poses many problems to the recycling of electronic products. APC identified three areas where contamination issues need to be addressed in order to overcome technical and economic challenges and enable recycling to succeed.

- The demanufacturer needs to receive the targeted electronic equipment and not other miscellaneous unwanted equipment that would contaminate the valuable materials.
- The processor needs to remove whole parts that meet the rejection criteria to limit problems such as coatings, paint and glass filler or labels, lamination, structural foam and composite plastics. Even small amounts of these contaminants can cause serious problems in recycling processes and, therefore, must be removed prior to processing.
Processors of plastics, or other material streams, desire obtaining the purest stream possible. Identification and separation equipment should be developed so that processors can cull the material down to the highest quality possible. This is important for marketability of recycled materials. (Plastics from Residential 1)

APC recognizes that even if the characterization and the contamination issues are resolved, they have yet to determine what markets can use the materials found in consumer electronics; what value the materials have to those markets; and the level and complexity of separation that is necessary to get the materials into a form in which they can be used. Until APC and other stakeholders have answers to these questions, it is difficult for them to determine whether recycling plastics and other materials from consumer electronics is an effective resource management tool. (Plastics from Residential 1)

APC and others are questioning whether recycling electronic equipment makes economic sense. The EPA analyzed the economics of five different residential electronics collection programs. The EPA concluded that most current programs run at a net cost. They found that it cost between 3 to 35 cents per pound for one-day collection events and from 7 to 28 cents per pound for other programs. These figures include collection, demanufacturing, and disposal costs minus any
revenue received from the sale of equipment and materials. (Plastics from Residential 1)

Currently, Hewlett Packard also questions the economics of recycling. HP’s recycling effort is aimed almost exclusively at products collected from its commercial customers, who tend to replace equipment frequently, when it still has relatively high resale or salvage value. First, in order to expand their recycling program, the company would need a much larger and more costly program to recycle the consumer products that make up a growing portion of their business.

Secondly, HP claims the recycling operation is unprofitable for the company and most of the losses are because of the high cost of shipping waste, for example, plastics, PC monitors and other items containing CRTs, to Noranda’s Canadian smelters. There, the CRTs are crushed and smelted to recover their lead content, while the plastic is burned for fuel.

Thirdly, it currently remains cheaper, at least for now, to simply burn the plastic and smelt the glass for lead removal. HP states that if companies or the electronics industry could figure out a way around these two issues then companies would have a more viable business model. The industry has not
figured out how to turn a profit on electronics recycling, especially when collection and transport costs are included. (Arensman 1)

3. Lack of Infrastructure

Various trade groups, including the American Electronics Association, state that PC firms believe the cost of taking back all of their old products and revamping their manufacturing processes would be too onerous and a barrier to trade. (Nash 1) The problem with the electronics industry is that it is not economically capable of fully demanufacturing or recycling its products. It lacks the infrastructure, or the underlying base or foundation, to enable the industry to take back its products and then recycle or reuse the components that make up the products.

John Hanson, executive director of the Recycling Council of Ontario in Toronto, states, “The rate of obsolescence in computer and electronics industries is so incredible that you have vast quantities of waste entering the waste stream, and the infrastructure to deal with that hasn’t developed.“ Many users believe computer companies should take back out of date equipment. Some computer companies do take back used equipment but usually only for their largest customers. According to Gary Kelman, an officer at the National Association of Environmental Professionals, solid waste collection companies would like to see computer manufacturers use safer, nontoxic materials. Computer manufacturers
say that local governments should set up facilities for the collection and disposal of computer waste. All stakeholders can agree that waste electronics are a mix of varied materials that make separation and recycling difficult and time-consuming. (Nash 1)

Research performed by Philips Consumer Electronics representatives in the Netherlands studied the problems with building up an end-of-life industry infrastructure for consumer electronics products in Europe. It is possible that these same problems can be stated for the U.S. Differences of opinion exist between government and industry. Among the issues were:

1. Government representatives within the European Union (EU) were of the opinion that producers and importers should be obliged to take back the used products unconditionally. Industry representatives did not want to accept this proposal because of the high financial risk.

2. Government representatives believe producers and importers are obliged to accept full producer responsibility. Industry representatives emphasized the shared responsibility of all those involved, not just producers and importers. Besides the producers of consumer electronics (manufacturers, remanufacturers, assemblers, importers) and suppliers (of raw materials, subassemblies, components), these actors also include
distributors, users, waste managers and public authorities (local and central).

3. Opinions were divided on the question of which improvements should be implemented, at what cost, and within which timeframe. At present, the high take-back and end-of-life processing costs are a serious handicap. These high costs are due in particular to the high labor cost of collection and disassembly and the low secondary value of some recycled materials.

4. Government representatives argued that the take-back system must be free of charge for households and that the cost of collecting and processing consumer electronic products must be included in the retail price. Industry, however, feared that this financing system will distort competition if free-riders do not implement the price increase. It can also lead to one-sided product responsibility on the part of the producers of consumer electronics. (Cramer 129)

The research summarizes, “The major points of debate can be traced back to the issue of who pays which costs and who is responsible for which end-of-life activities in the area of consumer electronics.” The research stated that the overall cost/benefit ratio of the take back of consumer electronics products is negative. The present end-of-life cost fluctuates depending on whether eco-
design has been applied. The cost of the end-of-life treatment relates to all phases of the end-of-life processing. The benefits are mainly gained in the phase of processing and recycling. The amount of valuable materials that can be recycled or processed is critical to the potential benefits. Given these differences of opinion, the major challenge is to formulate a model infrastructure for a better end-of-life treatment of consumer electronics which is acceptable from both an economic and an environmental point of view. (Cramer 129)

The first Electronics and the Environment Recycling Summit in the U.S. was held in May, 2000. This summit provided an opportunity for all stakeholders of electronics recycling and interested parties to gather to discuss issues and opportunities involved in the recycling of electronics products in the U.S. The event provided a unique opportunity for attendees to participate in discussions concerning the challenges of building an efficient and effective infrastructure in the U.S. Those attending were able to identify industry problems with establishing an infrastructure:

1. **Problems with Communication**

   - Existing recycling infrastructure is poorly documented and unknown to many owners of electrical and electronic equipment attempting to recycle old equipment.
• Information on design practices to facilitate recycling and reuse is not effectively collected and communicated to product designers. Reuse and recycling benefits of improved product designs are not quantified and made available to product designers for consideration when making design choices.

2. Problems with Recycler Support

• There is a lack of consistent information available to product recycling organizations on materials content of products being recycled.
• Inconsistent generation of some recycled commodities impedes development of consistent markets for these commodities.
• Capacity and location planning is difficult due to lack of good information of quantities and types of waste electronics available by region.

3. Problems with Reuse and Recycling Pilot Projects and Demonstration Projects

• Small scale recycling pilots conducted over short durations in municipalities demonstrate demand for product recycling services, but do not adequately assess a wide range of collection, transportation, and processing options, including costs and environmental benefits.
• Development of new recycling technologies is hampered by lack of funding for equipment development, inconsistent supplies of materials to be recycled, and inconsistent markets for recycled commodities.

• Recycling options for many materials can not compete financially with lower cost incineration or landfill options.

4. Problems with Regulatory Interaction

• Regulatory requirements controlling collection, transport, and recycling of discarded electronic products add cost to recycling processes and impede development of cost effective recycling solutions.

• No voluntary recycling industry certification programs exist which provide governments and those disposing of equipment with adequate assurance that products are being disposed in an environmentally responsible manner, and in accordance with applicable legal requirements.

• Exemption of household consumers from most waste disposal requirements eliminates incentives for consumers to participate, both physically and financially, in recycling of used electronic products.

• There is a need for increased municipality involvement in establishing cost-effective collection processes for electronic products from households, building upon an existing waste collection infrastructure.

5. Problems with Research:
• There is a lack of good information regarding environmental impacts of disposal alternatives for various materials found in electronic products.
• There is a need for automated and more cost effective materials separation processes for commodity materials in electronic products.
• There is a need for lifecycle environmental impact assessments, risks assessments, and cost analyses for potential substitution of hazardous materials found in electronic products.

6. Problems with Measurement:
• There is a lack of standard performance assessment methodologies and metrics for recyclers to enable easy comparison and assessment of improvements.
• There is no adequate process for collection of information on existing recycling and disposal processes for electronic equipment.
• There are no standard methodologies for quantifying and measuring improvements in product designs to facilitate reuse and recycling.

For each of these problems, the summit attendees were able to identify resources, including websites, that provided additional information on the subjects discussed. (Electronics and the Environment 1)
B. Overcoming the Problem

1. Product Lifecycle Assessment and Management

Product Lifecycle Assessment and Management provides a method to understand how the making, use or disposal of products affects the utilization of resources such as energy and raw materials, and generation of pollution. It can be helpful in determining how to design a product, run a manufacturing plant, or choose between products made from different raw materials. (Wythe 1)

Through each stage of a product’s lifecycle, energy and materials are consumed and waste products are generated. At each stage, there is the potential for reduction of solid waste through product reuse and recycling. The lifecycle assessment highlights the importance of product design and where key decisions need to be made that affect resource utilization and pollution generation throughout the system. (Wythe 1) Ideally, “completing the lifecycle” is the continuation of production by using reuse and recycling. This type of lifecycle, or closed-loop, emphasizes the fact that products can be reincarnated into new products, with either higher or lower value, through reuse and recycling. (Closing the Loop 1)

Before a lifecycle assessment can occur, the stages of the lifecycle need to be understood. A product’s lifecycle has three main stages according to research performed by Georgia Institute of Technology, Systems Realization Laboratory.
Product Lifecycle Stages:

- The first stage of the product’s lifecycle is **Production** (raw material extraction, manufacture, assembly) and **Distribution**.
- The second stage is **Product Use** (consumer and service).
- The third stage is **Post-Use** which could involve disposal, incineration, reuse or recycling. If disposal or incineration is chosen then this is the product’s final disposition.
- *If the product is reused or recycled and put back into Production, then the lifecycle has been completed.* (Closing the Loop 1)

![Figure 1: Product Lifecycle Stages](image)

*Figure 1: Product Lifecycle Stages* (Research Summary of Lifecycle Engineering at Stanford University Newsletter 1)
Recycling is included within the many stages of a product’s lifecycle. If recycling occurs during or after production and distribution, but before it reaches the customer, it is referred to as “pre-consumer” recycling. If recycling occurs after the product is used it is referred to as “post-consumer” recycling. Pre-consumer recycling has the characteristics of high recycling value of the product’s materials and ease of separability or compatibility of materials. Reuse can occur when the product has the characteristics of a high reuse value and can be disassembled easily. This occurs in the Post Use stage of the lifecycle. (Closing the Loop 1)

Once the stages are identified then the lifecycle and the potential for “closing the loop” can be assessed. “The figure gives an overview of a closed loop reuse/recycling system that recognizes the critical need for feedback from the recycling operation to the design process. Implementation of this system model insures the accurate, timely and relevant data is provided to the design community for design evaluations and lifecycle cost analysis. In many cases the demanufacturing operation is already in place. These facilities are typically either owned by the manufacturer for product take-back purposes, or at an outside vendor or subcontractor’s facility. In some cases, data is currently being collected from these operations to assist the design community. However, by incorporating a team approach to the technical data collection process, designers assist in the refinement of data collection methodologies to guarantee the data’s utility. In addition, this team approach can focus attention on the environmental
and economic hierarchy of reuse verses recycling and create incentives for exploration of expanded reuse programs." (Boswell 143)

Figure 2: Closed loop reuse/recycling system (Boswell 143)
The goal of lifecycle design at Stanford University's Manufacturing Modeling Laboratory is to maximize the values of the manufacturer's line of products, while containing its costs to the manufacturer, the user, and society. Engineers must consider performance, costs, and environmental impact of not just one product, but entire product families and changes over product generations. The research develops systematic methodologies to allow engineers to integrate necessary functions, while maximizing ownership quality and minimizing lifecycle costs and environmental burdens. (Life-Cycle Engineering Design 1)

Investment Recovery is a process for obtaining the maximum return on surplus assets. “It is end-of-life-cycle asset management at its most complete.” The process identifies these assets for reuse, remarketing, or demanufacturing. Applied to surplus computer and electronic equipment, financial return to the asset owner with a well-run Investment Recovery operation is realized through the following:

- Purchase Avoidance – Avoidance of unnecessary new equipment purchases
- Cash Revenue – Cash income from sales
- Tax Reduction – Asset based tax reductions
- Tax Credits – Tax credits from in-kind donations
- Reduced Costs – Reduced disposal and recycling costs
- Reduced Legal Liability – Reduced risks of software license violations
Investment Recovery works by identifying surplus products usually the result of system upgrades, relocation of staff, or company reorganization. This surplus is inventoried and tested. Various classes of surplus are identified including products with reuse potential, remarketing potential, and demanufacturing potential. Materials that are retained for re-use are stored using effective warehouse practices. Materials to be disposed of are resold under varying collection scenarios based on resale value. It may be sold retail, wholesale, auctioned, brokered, bartered, donated, or demanufactured. (Weston 1)

Investment Recovery is challenging. In order to maximize the return on surplus materials it must have meaningful resale value and should be redeployed. In order to achieve that, the inventory and its condition must be known. (Weston 1)

Dr. Nabil Nasr has stated that electronic products are used for only a fraction of their useful life. Companies need to look for alternatives in order to utilize the rest of the lifecycle. Some examples of products that have expanded their lifecycle and closed the loop are the Xerox reusable toner cartridges and Kodak's reusable cameras. Electronics products should find a way to expand the
lifecycle, possibly by replacing only the board in a computer and design the rest of the computer for reuse such as the cables and power case.

In order for companies to take the initial step toward closing the lifecycle loop, they need to have an understanding and acceptance of the residual value of their products and of environmental stewardship, according to Nasr. Companies such as Xerox and Kodak did make the effort to understand these values and realized that it was economically beneficial to the company at the same time.

Nasr also states that if companies are not willing or capable of understanding these values then they will need a push by the government to start reuse and recycling. In these cases the government will have to provide incentives and technical assistance. Some incentives may include preferred treatment or reduced taxes for those meeting the government standard.

One example of a company that has followed a lifecycle approach to reducing waste generation is Xerox Corporation. They have a comprehensive lifecycle approach to products, called “Asset Management”. Asset Management is a corporate-wide program at Xerox that has changed materials selection and product design. Xerox’s comprehensive program involves product take-back, reverse logistics, design for disassembly as well as reuse, remanufacturing, and recycling. Additionally, the company has environmental guidelines for the
preferred management of the products it takes back. This type of approach could be considered “Extended Producer Responsibility”. (Fishbein, 1)

Xerox Corporation has an equipment remanufacture and parts reuse process that is the “industry benchmark” for supplies return and reuse/recycling. Xerox has had a well-established return infrastructure since the early 1990’s. The company has been able to “maximize the end-of-life potential of products and components by building the concepts of easy disassembly, durability, reuse and recycling into equipment design.” They are able to say that 90% of Xerox-designed equipment is remanufacturable. This process prevented more than 148 million pounds of waste from entering landfills in 1999. Parts reuse reduces the use of raw materials and energy needed to manufacture new equipment. Additionally, the financial benefits amount to several hundred million dollars a year.

2. Extended Producer Responsibility

“Extended producer responsibility“ (EPR) is a strategy that encourages a closed-loop pattern of materials use. The producer’s responsibility extends across the lifecycle of the product particularly to the post-consumer stage. Under EPR, a company must be concerned with making the product, how it functions and what will become of the product at the end of its useful life. In the case of consumer goods, this principle shifts responsibility for recycling and waste disposal from local government to private industry. The costs of waste management are
internalized into product prices. Therefore, waste management is paid for by the consumers when purchasing products. EPR programs aim to increase recycling and achieve mandated recycling targets. (Fishbein, 1)

Europe has taken the lead on reducing electronics waste by using EPR and by making producers responsible for taking back their products. EPR encourages producers to reduce resources and energy usage and to practice pollution prevention in each stage of the product lifecycle. This occurs through changes in product design and process technology. EPR is the principle that producers take increased responsibility for all of the environmental impacts of their products. This includes upstream impacts arising from the choice of materials, the manufacturing process, and the downstream impacts such as the use and disposal of products. EPR focuses on the responsibility of producers to take back their products at the end of their useful life either directly or through a third party. (Just Say No 1)

State Recycling Laws Update, a newsletter covering recycling events and news, performed a study involving state recycling managers. More than 90% of these managers responding to the survey indicated they favor “some form of ‘producer responsibility’” in the U.S. The survey asked if states have a strategy for dealing with electronics waste and if landfill bans would help. 26 of the 35 responding to the question felt that landfill bans of electronics would help encourage producer
responsibility. Many also felt that some sort of shared responsibility approach by all stakeholders would help in dealing with electronics recycling. (Majority of Recycling 1)

Others have stated, using computers as an example, “To be most effective, computer recycling is a problem that must be solved at both ends: Make design changes that will make new computers easier and cheaper to recycle but at the same time build an infrastructure to dispose of old computers.” (Schuessler, “PC” 1)

In the case of consumer electronics, EPR shifts responsibility for recycling and waste disposal from local government to private industry. The costs of waste management are worked into product prices. Citizens would now pay for waste management as consumers when purchasing products, rather than as taxpayers through local taxes. EPR programs typically are aimed at increasing recycling and often contain mandated recycling targets. (Fishbein 1)

EPR is intended to reduce the amount of materials going to landfills but it is also concerned with product design and material selection. The theory of EPR is that if producers must pay for waste, they will have an incentive to make products that are less wasteful. “EPR provides the missing link between product design and recycling: a link that is key for making recycling efficient and economic.” Design
for disassembly, reverse logistical systems, and demanufacturing are strategies industry has used to incorporate EPR into electronic products. (Fishbein 1)

Design for disassembly, reverse logistical systems, and demanufacturing are all enablers to reusing a product or its components. The three R’s typically associated with environmental practices are reduce, reuse and recycle. In terms of resource management and environmental impact, recycling alone is not necessarily the best option. Recycling reduces waste and landfill usage at the end of a product’s lifecycle but the waste is not minimized. Recycling affects the environment by consuming energy during product collection, sorting, cleaning and separation which in turn causes air and water pollution.

Reduction or waste minimization would involve examining the production process for efficient energy and material use and design for durability. Currently, the best option for the most viable recovery system would be to incorporate reuse, remanufacturing, and recycling to optimize the value of the equipment collected. As more collection services are established, the greater the volume collected. “Greater volumes will make it more feasible to establish an operation which justifies the level of sorting necessary to optimize the use of different markets. It is also more likely to be economically sustainable and to be of the greatest environmental benefit.” (Welstead 159)
These greater volumes will only be captured if a functional infrastructure for the electronics industry is established. The New England Recycling Coalition (NERC) is an organization composed of recycling coordinators of the Northeast states. At NERC’s fall 2000 meeting, the Electronics Industries Alliance (EIA), Canon, Sharp, JVC, Panasonic and Envirocycle successfully convinced recycling coordinators from 50 Northeast states that a “viable market infrastructure for the reuse and recycling of used televisions and computers will only occur through the involvement of all stakeholders.” The focus of the meeting was to develop strategies to support a regional recycling market development policy for used electronics. The policy will serve as a “blueprint” for state decision-makers and stakeholders for designing laws, regulations and programs. Additionally, the states were convinced that manufacturer responsibility is not the answer to the increased disposal of used electronics. (EIA Attendance 14)

3. Infrastructure Establishment

Many electronics producers, recycling companies, interest groups, and individuals have been brainstorming to create an infrastructure that would support the needs of the industry. Steve Skurnac, president of Micrometallics, Inc., has defined an “Asset Recycle Infrastructure” which was presented at the Environment Recycling Summit in May 2000. An asset recycle infrastructure is a foundation or framework on which a company can depend to handle all its asset recycle and disposition needs. He defines assets as anything a company owns,
has value, or potential value. This could include new equipment, parts and materials from manufacturing excess and scrap, excess / surplus / cancelled / obsolete products, or customer service returns. It could also include returns, trade-ins and mandated take-backs. (Skurnac 1)

Researchers from Philips Consumer Electronics broke down the phases of end-of-life processing, or stages within an infrastructure to assess the costs associated with each phase. The phases are:

1. **Collection and transport** from the final user to disassembly and recycling companies. This could possibly be retailers, local authorities and/or industry.

2. **Disassembly** including dismantling steps for separating the main, valuable parts, and detailed separation of specific small parts.

3. **Mechanical processing** involves the application of a shredder and other separation techniques.

4. **Processing** including recycling, such as plastic regranulating, glass re-use and copper smelting.

5. **Final disposal** of wastes such as impure plastics, non-recoverable metals and residue. (Cramer 129)
According to Skurnac, companies are looking for several elements from an asset recycle supplier. Companies want a full service provider that will provide transportation, component strip, component and unit resale, destruction, zero landfill, and revenue from the commodities market. Additionally, OEM’s are looking for many qualities in a supplier. This includes certification to an environmental management system such as ISO 14001, financial stability, open business disclosure, good tracking, reporting and documentation, validation, indemnification and a process-capable electronic recycler. Of great importance is that the supplier have national and international support with strategic locations, excellent customer service, a high degree of flexibility and one supplier for all of the asset recycle business. To summarize, the asset recycle infrastructure is comprised of these aspects:
Figure 3: Aspects of an Asset Recycle Infrastructure (Skumac 1)

These aspects, however, do not currently exist together as an infrastructure. There are many development opportunities. In order for the transportation aspect to exist, logistics such as forming a national or local transportation partnership, shared transportation services, or manufacturer provided transportation, need to be determined. In order for environmental disposition to occur, providers or provider partnerships need to be established. This may consist of a network of regional and local companies that share transportation services and the economies in volume but specialize in different commodity types. Government legislation also factors in the development of an infrastructure. Those in the electronics industry must be willing to support legislation that would enhance the infrastructure development process. Those involved must be able to stay current and up to date on all local and national initiatives and customer requirements. Possibly the most important aspect to the infrastructure is market capability. Development of local markets, worldwide
markets and new uses for materials is of greatest need in order for an asset recycling infrastructure to exist. (Skurnac 1)

IAER Workshop Focus Groups Summary Report on Infrastructure states that the needs for an infrastructure include:

- No capital without markets
- Tax credits for investments
- Environmental derivations
- Uniformity in regulations
- Transportation study
- Market development for outputs
- Customer survey
- Product stewardship from OEMs
- Government / Industry partnerships

(IAER Workshop 1)

Researchers from Philips Consumer Electronics concluded that “optimum results in terms of preservation of value and resources can only be achieved if matters are organized based on shared responsibility. Responsibility should be assigned based on the ability to manage and to get maximum environmental results at a minimum cost. It is expected that such results can be achieved in the following way:
Households should be allowed to deliver free of charge to collectors.

Collection of consumer electronic waste should take place simultaneously with other waste streams, preferably through municipal collection because of the infrastructure that already exists.

Separating and dismantling sites. Waste is separated into appropriate waste streams via product selection and dismantling stations.

(Cramer 129)

4. Non-U.S. Initiatives

Government and industry may find themselves working together to establish an infrastructure. The European Union has proposed legislation that mandates producers of electrical and electronic equipment be physically and financially liable for their products at the end of their consumer life. Japan has similar legislation that will take effect soon for certain products. In anticipation of these legislations, some U.S companies have instituted take-back programs in Europe and Asia. These same companies, however, are not showing the same leadership in the U.S. Some companies are even resisting efforts to implement programs in the U.S. For example, Apple has implemented take-back and recycling programs in Germany but not in the U.S. Dell has programs in Germany, Sweden, Norway, the Netherlands, and Taiwan but not the U.S. IBM
has been involved in electronics take-back in Europe since 1989 and only recently announced a program in the U.S. Interestingly enough, the U.S. program requires consumers to pay a fee while some European and Japanese programs are free of charge to consumers. Since 1996, Sony has provided financial incentives for consumers to bring back old monitors for recycling at their many centers in Germany. In the U.S., Sony has recently announced a new recycling center, but provides no financial incentives. (Takeback 3)

The Netherlands, Sweden and Switzerland have adopted varying recycling mandates and regulations for the disposal of hazardous substances from used electronic products. In Asia, Taiwan and Japan both passed laws requiring electronics makers to take back and recycle computers, TVs, refrigerators, washing machines and air conditioners. Taiwan’s law has been in effect since 1998, while Japan’s took effect in April 2001. (Arensman 1) The Ministry of International Trade and Industry (MITI) in Japan has also mandated that computer manufacturers and importers reuse at least half the materials and parts from recovered computers by 2003. (MITI Working 1)

In Korea, the Korea Electronic Industry Environment Association (KEIEA) was established in September 2000 and immediately started the process of constructing waste electronic treatment facilities in several areas around Korea. This is the first step towards establishing a nationwide waste electronic product
take-back and recycling system. KEIEA seems to have a relationship with the electronic manufacturers Samsung, LG and Daewoo, who have the necessary infrastructure (mainly through their local branches) for collecting used goods throughout Korea. (South Korea Electronics 1)

Early in 2001, Hewlett Packard Japan Ltd. started recycling old computers and peripherals free of charge for customers who buy PCs through the company’s website. The service, designed jointly with Tao Co., Tokyo, is intended to increase HP’s web-based sales. Tao will be responsible for collecting the equipment at its disposal centers in Kanagawa Prefecture and Osaka. A fee will be charged for pick-up of the waste, however, if the equipment is dropped off, then no fee will be charged. Tao will then process and recycle the equipment. Some monitors will be sent to partner companies in China and some equipment will be resold through their website. Tao plans to partner with other companies like Hewlett Packard and also extend its recycling services to individuals when new mandates take effect. Tao would like to work with other foreign computer importers that lack recycling facilities within Japan. Japanese manufacturers have been working to have recycling systems in place by April 2001 when the country’s mandate takes effect. (Tao, Hewlett-Packard 15)

Norway has experienced an increase in the recovery of electrical and electronic equipment since a July, 1999 ordinance took effect. This ordinance attempts to
ensure that at least 80% by weight of electronic waste is collected annually by July 1, 2004. The Ministry of the Environment in Norway has vowed that it will help create favorable conditions for the effective collection and recycling of electronics wastes. The Ministry will also assist with program compliance by implementing education programs to promote collection and recycling. The country collected about 7,500 tons after one year of the program. This is about 5% of the approximately 144,000 tons of electronics waste generated per year according to a 1997 estimate made by the Norwegian Pollution Control Authority. Norway has seen about a 50% recycling rate for all waste products on the market after the implementation of the 1999 ordinance. (Norway: Recovery, 11)

The infrastructure in Norway begins with three material companies responsible for recovery. They have administrative operations that buy services from subcontractors in the fields of collection, transportation and recycling. These companies have divided Norway into five regions where subcontractors have different contracts for collection, transportation and recycling in order to avoid monopoly situations. The manufacturers and importers add environmental fees to their invoices down the distribution chain, making the consumer pay the fees at the end of the line. Two of the three companies have decided to collect electronic waste from all retailers and municipalities and 71 collection points have been established. The retailers and municipalities must pay their own delivery costs. The value of these material companies' contracts with the subcontractors
in the first 12 months (1999-2000) is estimated at approximately 316 million NKR. (Norway: Recovery, 11)

Norway’s system of collection is one of the first national recycling systems for waste electronics in Europe. Several European Union member states have already drafted electronic recycling legislation including the Netherlands, Denmark, Sweden, Austria, Belgium, Italy, Finland, and Germany. The new WEEE Directive attempts to merge the legislation of these countries to allow industry to operate under a similar, uniform system throughout Europe. The European Commission’s WEEE Directive, based on the Extended Producer Responsibility concept, is being legislated because electronics waste is growing about three times faster than the growth of other municipal waste and the hazardous components of the products pose waste management problems. It is estimated that 90% of the waste is landfilled, incinerated or recovered without any pretreatment. (Just say no 1)

Governments around the world, most notably in Europe, are adopting or considering a range of new “extended producer responsibility” laws to encourage electronics producers to share all or part of the cost of recycling their products at the end of their useful life. In June, 2000, the European Commission, a body of the European Union, approved a draft of the European Directive on Waste Electrical and Electronic Equipment (“WEEE Directive”), which would require
makers of electronic and electrical goods to pay for collecting, recycling and disposing of waste equipment. A separate European Commission directive proposes the phase-out of numerous hazardous substances, including selected heavy metals (such as lead, mercury, cadmium, hexavalent chromium) and flame retardants, from European electronics products by 2008. Both directives require approval by the European Parliament and Council of Ministers before becoming law which is expected by 2002.

The proposed WEEE Directive aims to prevent waste of electronic and electrical equipment; promote reuse, recycling and recovery of such waste; and minimize risks and impact to the environment associated with treatment and disposal of end-of-life electronic and electrical equipment. The proposed directive aims to set tough targets on equipment collection and encourage design for disassembly. (Draft EC 1). It would require electronics manufacturers to recycle 60 – 80% of consumer and industrial electric and electronic products by 2006. The proposal plans for consumers to return electronic items to designated municipal collection centers free of charge. The municipalities will subsidize the collection centers and producers will pay for handling treatment, recovery, and disposal. The European Commission hopes the directive will provide incentive to design recyclability into products initially by requiring producers to take back their equipment. The environment will benefit by preserving more open space, conserving natural resources, saving energy and reducing pollution. (Dwortzan 1)
Because the WEEE Directive is based on the Extended Producer Responsibility concept, the objective of the directive is “to require manufacturers to improve the design of their products in order to avoid the generation of waste and to facilitate the recovery and disposal of electronic scrap.” (Just say no 1) The Silicon Valley Toxics Coalition (SVTC) states that EPR can be achieved through the phase-out of hazardous materials and the “development of efficient systems of collection, re-use and recycling.” SVTC also states that “Ultimately, the goal is to close the loop of the product lifecycle so that producers get their products back and assume full responsibility for lifecycle costs. By ensuring this feedback to the producer and by making them financially responsible for end of life waste management, producers will have a financial incentive to design their products with less hazardous and more recyclable materials.” (Just say no 1)

Additional other requirements are proposed in the WEEE Directive to ensure extended producer responsibility. Member states must encourage producers to integrate an increasing quantity of recycled material in new products. Producers must design equipment that includes labels for recyclers that identify plastic types and location of all dangerous substances. Producers can perform the take-back treatment operation in another country, but not to a non-EU countries where no or lower treatment standards than in the EU exist. Producers must deliver
waste electronics only to certified establishments and producers shall verify compliance through adequate certifications. (Just say no 1)

The EC estimates that a 1% hidden price increase would cover the total business recycling costs for most products. It is hoped that eventually this cost will disappear due to lower costs for production and disposal and more efficient product design. Many producers seem concerned about the additional cost and would rather see a “visible” fee on the new products so the consumer will see that part of the cost will go to recycling. (Dworzanz 1)

5. U.S. Initiatives

a) Government, Community and Interest Groups

The European Union and Norway are not the only government entities trying to tackle the electronic industry’s waste. In the U.S., Hennepin County, Minnesota, which includes Minneapolis-St. Paul, recovered more than 50,000 computers from residents. Massachusetts recently banned the disposal of cathode ray tubes (CRTs) in landfills, and New Jersey, North Carolina and other states are evaluating options for electronic-product waste. (Alster 1)

In the absence of U.S. federal guidelines, other entities such as states, government agencies, activist groups and communities are taking some action to
control waste electronics. Several states have recently passed laws regulating the disposal of potentially hazardous substances such as lead, cadmium and mercury, which are currently used in many electronics devices. In April 2000, Massachusetts adopted regulations banning cathode ray tubes (CRTs) from landfills, transfer stations and incinerators. The state is trying to encourage recycling of the materials which can now be taken to one of six regional collection centers. According to the Massachusetts Department of Environmental Protection, a CRT averages five pounds of lead. Electronics currently account for 75,000 tons of solid waste in Massachusetts per year which is expected to increase to 300,000 tons per year by 2005. (Doler 1) Before implementing the new laws, the state set up six centers to collect discarded CRTs and other electronic equipment. Two companies recycle the material that is collected. (Arensman 1)

Another state, Arkansas, is taking action by proposing legislation that would place a $5 fee on each computer purchased in Arkansas. The money collected would fund a recycling grant and loan program. The legislation also bans landfilling computer and electronic equipment and imposes detailed requirements for treatment of old computers by state agencies. (State Post 2)

In December 2000, the Northeast Recycling Council agreed on a general policy statement where member states are encouraged to support increased recovery
of electronics. The statement recommends that members provide economic assistance to support the development of economically viable used equipment recycling businesses, promote standardization of material (particularly plastic), and decrease use of toxic materials in electronics. It also supports promotion of better designs, and market development for recycled feedstocks, and encourages uniform purchasing standards for backup operating software. The statement includes references to new public policies: “implement, on an as-needed basis, mechanisms to help cover costs associated with the recovery, reuse, and recycling of used electronics. Options could include, but not be limited to advance disposal fees, reverse distribution systems, customer rebate programs, deposit and return systems, or other mechanisms that capture the costs of managing used electronics through the pricing of new electronics products and utilize the funds generated to cover those costs.” The statement includes another action step to promote leasing of electronics and to consider policy options including bans to keep CRTs from landfills and incinerators. Another action step encourages the member states to evaluate current regulations to ensure they do not impede recycling of electronics. It also recommends establishing a current baseline for used electronics recovery in the Northeast, and to set recovery goals. (Policy Statement 5)

Activist groups such as the California Resource Recovery Association (CRRA) are taking an initiative also. CRRA is initiating a producer responsibility
campaign by sending out letters aimed at major electronics makers. The campaign will extend to cover all of the U.S and then internationally. CRRA claims the letters are “friendly” and emphasize to the receivers that the public wants a take-back program and that local governments cannot continue to bear the cost. CRRA states that Local governments are used to coming up with a collection program and an estimated cost for that program and then request the funding. Specialty items such as highly technical electronics products, however, bear a higher cost. CRRA believes the responsibility should be shared and when a product is developed the producer should plan to make it collectable, repairable and recyclable within any community. Manufacturers of electronics products need to plan for take-back programs across the country, not just in a specific region. (Electronics Activists 1)

Organizations have been established in recent years to specifically try to address the issue of electronics waste. The International Association of Electronics Recyclers, Inc. (IAER) is the first and only trade association for the electronics recycling industry. It was formed to represent and serve its interests as a key element in the development of an effective and efficient infrastructure for managing the lifecycle of electronics products. The mission of the organization is “to serve the interests and needs of Electronics Recyclers and related organizations in the development and growth of the electronics recycling industry, including to:
• Identify solutions to business and technical needs
• Influence public policy and knowledge in relation to the industry
• Establish industry standards for business practices
• Maintain awareness of regulations and legislation that affect the industry
• Provide access to industry data and information
• Facilitate opportunities for partnerships and business development

(General 1)

The Scope of Interest of the organization encompasses all phases of activity associated with the recycling and reuse of electronics products, parts, and materials, including the following market segments:

• Asset Management – e.g., disposition planning, resale
• Reuse - e.g., as-is, surplus, and refurbish
• Demanufacturing – e.g., disassembly for re-use of parts and subassemblies
• Parts Recovery & Reuse - e.g., electronic, mechanical, electro-mechanical
• Materials Recovery & Recycling – e.g., plastics, precious metals, glass, paper
• Metal Refining – e.g., copper, aluminum, steel, lead, precious metals

EIA announced an industry-led effort to encourage consumers to reuse and recycle used electronics such as TVs, PCs, VCRs, and cell phones. The effort, named the Consumer Education Initiative, or CEI, includes a website,
that directs users to local charities, needy schools, neighborhood and community demanufacturers, and other local and national recycling programs that collect used electronics. “With the growing number of obsolete electronics, it is essential that the U.S. high tech industry proactively develop programs to preserve and protect the environment, and the Consumer Education Initiative is a big step in that direction,” said Dave McCurdy, EIA President. “Our goal is simple: we aim to lessen the environmental impacts of our products throughout their entire life cycle, from design to end-of-life.” The Consumer Education Initiative is a comprehensive web-based information resource that provides consumers and others with information on recycling and reuse opportunities for used electronics. The program is a result of hundreds of meetings with federal, state and local government officials, industry representatives, environmental groups, and reuse, recycling, and disposal organizations. (EIA Press Release 2/1/2001) The CEI program also urges members to design for disassembly, eliminate or reduce substances that can impede recycling, and make products smaller so there is less waste. Leaders in the environmental committee include Sony, Sharp, Hewlett-Packard, Intel, IBM, and Panasonic. (EIA Members 1)

b) San Francisco Recycling

The San Francisco Waste Management Program started a city-wide partnership with computer retailers and recyclers in September 2000. The intent was to
manage electronic waste and divert it from landfills. The voluntary project, known as the Computer Recycling Pilot Project, directs consumers to eight participating retailers in San Francisco to dispose of old computers. The retailers then work through four participating recyclers. In the first month of the project, over 50 computers were collected. (Computer Recycling Project 1)

Lisa Schiller, Residential & Special Projects Associate for the San Francisco Recycling Program, said the immediate focus was on computers since the infrastructure was already located in the San Francisco Bay area. She stated, “We developed an idea that would work with computer retailers, and then discussed this concept of having computer retailers take back the materials from residents for free, with those retailers in turn interacting with the computer recyclers in the Bay area, specifically in the city, to remove the material and go recycle it.” There are eight different retailers in the city that agreed to participate; all small, independently run stores. Four recyclers participated, two for profit and two non-profit. The two non-profit recyclers work with school districts. The two for-profit recyclers disassemble the computers, remove the lead and crush the glass, for complete disassembly and recycling. The project is entirely funded by the participants. Each entity is subsidizing its participation. (Computer Recycling Project 1)
c) Sony in Minnesota

Minnesota has been touted as a leader in electronics recycling by having conducted several pilot studies on the costs and likely results of residential electronics waste collection. Hennepin County Minnesota (includes the Minneapolis metropolitan area) has been recycling electronics waste since 1992 in an effort to reduce the heavy metals in its solid-waste incineration system. (Arensman 1)

In October, 2000 Sony Electronics Inc., a Park Ridge, NJ-based unit of Sony Corp., selected (Minnesota) to launch the country’s first electronics “take-back” program in cooperation with Waste Management Inc.’s Asset Recovery Group. “It’s an acceptance that we as a company have a shared responsibility.” (Arensman 1) Sony Electronics Inc. has an agreement with the state of Minnesota to guarantee recycling of Sony products for five years. This is a voluntary program, expanding on a pilot program that was conducted in the state. The program establishes drop-off locations through a contract with Waste Management Inc. Sony electronics and personal computer equipment can be dropped off at any of the three sites in the Minneapolis-St. Paul area at no cost. Sony is funding the program and there will be no additional cost imposed on consumers. (Sony Commits 2)
Sony would like to see the program expand with many other electronics manufacturers participating and recycling their own products. If enough do...the resulting economies of scale should reduce, and perhaps even eliminate, the manufacturers’ subsidy. “The ultimate goal is to reduce the cost to zero within the next five years”. Based on earlier studies, Sony believes it can finance the collection and recycling of its own products for about 8 cents a pound. That’s well below the 25 cents a pound the company expects to spend next year in Japan, under that country’s mandatory take-back program. If the Minnesota program goes well, Sony intends to expand it to at least one more state this year, and nationwide within five years.” (Arensman 1) Sony hopes that the program will reduce the need for government legislation to remedy the electronic recycling issue. (Sony Announces 13)

Tony Hainault from the Minnesota Office of Environmental Assistance is trying to work with other electronics companies and gain participation from Best Buy retailers. Some observers of the program have said retailers have been the most reluctant player in the electronics production chain. (Sony Commits 2) Best Buy Co. announced at the Electronic Product Recovery and Recycling Conference that it would be the first retailer in the U.S. to offer a broad-based drop-off program for electronics recycling. In summer 2001 they will conduct a pilot phase involving local governments, recyclers and OEMs. Panasonic will be the
first manufacturing partner in the program. The proposal calls for a consumer drop-off fee.

d) IBM Takeback

In November 2000, IBM expanded its existing recycling program and initiated a new program to take back personal computers and associated equipment from individual consumers and businesses. Unlike most electronics companies, IBM’s PC Recycling Service accepts old computer equipment from consumers and small businesses from any manufacturer of PCs, system units, monitors, printers and optional attachments for a fee of $29.99 which includes shipping through UPS. The equipment will be recycled through Envirocycle, a recycling company in Halstead, PA. Customers are able to purchase the recycling service with new IBM products or separately. The old equipment will be reused or recycled where able, with any usable equipment refurbished and donated to Gifts-in-Kind International for distribution to nonprofit organizations. IBM’s services help to facilitate the recycling of unwanted or obsolete equipment. IBM also helps to ensure equipment that is still of value is made available to others who can benefit from it. (IBM Announces 1)

The IBM PC Recycling Service is an expansion of the company’s existing recycling programs, which have been processing end-of-life formerly leased equipment since 1985. In 1999, IBM recycled over 120 million pounds of
equipment parts. Less than 4% was unsalvageable or non-recyclable. (IBM Starts 4) IBM has developed a variety of solutions to reuse and recycle returned electronic equipment. Their goal is to recycle as large of a percentage of collected materials as possible. They use a hierarchy of disposition options that depend on the recyclability and the value of various computer residues. Products and service parts are recovered, repaired and recertified for reuse. Other parts and components are recovered and resold to secondary markets. Computer end-of-life residue that cannot be either remarketed, refurbished or recovered is recycled where possible, beginning with the elements that are least costly to recycle and bring the most value such as chips and precious metals. (Product End 1)

IBM has a partnership with Gifts in Kind International and has donated more than 5,000 used personal computer systems to non-profit organizations. Used computer materials are collected at numerous Materials Recovery Centers around the world. In 1996, IBM reutilization centers processed over 88 million pounds of discarded IT equipment. Over 85% was either reused or recycled. Less than 7% was sent to landfills. (Product End 1)

IBM Global Financing (IGF) has expanded to include Asset Disposition and Support Services for midrange and large customers. Some new options include inventory analysis and indemnification for customer-owned assets that are
scrapped acquisition of used information technology equipment and
redemption of assets. (IBM Announces 1)

Ted Smith, executive director of the Silicon Valley Toxics Coalition, advocates of
electronics recycling, said that IBM is taking a good step by accepting individual
an businesses computer waste but that he prefers the European Union’s
proposed approach of a manufacturer to take back and regain ownership of a
product. If a manufacturer is responsible for the life-cycle of a product, such as a
computer than the company will design the product to be more easily recyclable.
(IBM Unveils 1)

“IBM, which operates the world’s largest electronics recycling plant in Endicott,
NY which recycles close to 90% of its mainframe and mid-range computer
products. The highly automated Endicott facility processed 40 million pounds of
aging electronics, much of which was salvaged as parts for sale or re-use.
“We’re coming to the point where it’s almost a break-even thing,” says Diana
Bendz, IBM’s director of environmentally conscious products and one of the
industry’s most experienced recyclers, who oversees the Endicott operation.
IBM thinks electronics recycling may eventually pay for itself, but only after
systems are in place to collect and recycle huge quantities of used equipment.
She offers advice for companies just getting started: “The earlier they consider
this a business requirement, the more profitable it’ll be to them in the end. Until
you start recycling, everything you throw away is waste, and that’s dollars off the bottom line.” (Arensman 1)
IV. Conclusions and Recommendations

A. Research-based Conclusions

Based on the literature reviews and interviews conducted, it was found that many of the parties working closely with the electronics industry are following a path that will bring the development of an infrastructure to the U.S. However, this can only happen with the help of minor government involvement and a true commitment by those in the electronics industry.

Electronic products pose a significant waste generation problem. Technology is moving at such a rapid pace that these products are obsolete in a very short period of time thus creating an increase in waste. A solution to these problems is to increase the recovery, reuse and recycling of electronic products, components and parts.

There is a problem with this, however. The electronics industry in the U.S. does not currently have a way to effectively recover, recycle or reuse these products or waste. For those companies that do not have established systems, the possibilities that exist for the reuse and recycling of those wastes is limited. Additionally, there is not much incentive for companies to recover, reuse or recycle. They currently do not see a benefit. It is costly and companies are not regulated to do so. The system needs to change. An infrastructure must be
established in order to stay ahead of the ever-increasing electronics waste stream.

One solution is summarized by the participants of the Electronic Product Recovery and Recycling Conference held in April 2001 “Regulatory consistency, private-government collaboration, and the participation of the transport industry are among the actions needed” to develop an effective and affordable infrastructure to recycle electronic products. The participants identified four key areas where progress is needed to develop a recycling program. These are regulation, economic models, training and communication, and coordination between the research community and companies that recycle goods.

One regulatory policy is needed in order to overcome the industry’s current frustration with trying to comply with different state, federal and international regulations. This one policy must be clear, consistent and enforced. Other regulatory or government actions should be developed. These include federal procurement guidelines to increase the recycled content in products that agencies purchase; offering tax incentives to companies that increase the recycling content of their products or design them so they have less harmful impacts on the environment; paying premium prices for “environmentally preferable products”; and setting fees on products based on the hazard they pose. (Phibbs 811)
William Ferretti, executive director for the National Recycling Coalition, summarizes by stating, “It should be as easy to return a product for recycling as it is to purchase one.” Many believe municipal governments should not bear the cost and responsibility for collecting used electronic equipment and users should bear some portion of the cost rather than taxpayers. It is thought that industry, universities, and other interested groups should determine how recycling programs could be funded. (Phibbs 811)

Peter Muscanelli, president of the International Association of Electronics Recyclers, says transportation companies need to work with electronics manufacturers, recyclers, and regulators in trying to develop recycling systems. Transportation costs are among the most expensive part of recycling electronic products, and reducing those costs will be essential to a successful recycling program. (Phibbs 811)

A “platform” has been developed by the Silicon Valley Toxics Coalition and the Grassroots Recycling Network. This platform calls for manufacturers and distributors of electronic products to take a financial and/or physical responsibility for their products throughout their entire lifecycle by practicing Extended Producer Responsibility including taking the products back and recycling the material from which they were made. The platform would also like to see
manufacturers phase out the use of chemicals and metals, such as lead, mercury and chlorinated solvents, that can be harmful to humans or the environment. Companies should develop products that are easy to upgrade and to disassemble, which will make them easier to recycle. (Phibbs 811)

**B. Self-drawn Conclusions**

Through interviews and literature reviews, it was concluded that in order to solve the problem of electronic products not being recovered, reused or recycled in the U.S., an infrastructure must be established. The manufacturers participating in the infrastructure must first conduct a product lifecycle assessment. Secondly, the electronics producers must recognize the need for committing to extended producer responsibility. Only then will the infrastructure start to develop. Without these two “steps to realization” the electronics industry will not have the initiative, means, or endurance to make an infrastructure sustainable. These two steps will also allow electronics waste reduction despite today’s obsolescence and the decreasing life span of electronic products. If products are made with parts and components that are subsequently recovered, reused or recycled through the infrastructure, then much or all of the waste will be eliminated. This will result in less wasted resources and reduce the presence of toxic substances in the environment.

Other countries’ experiences and pilot projects in the U.S. have demonstrated that the infrastructure must involve many parties. Municipalities and waste
handlers are required for success. With the involvement of these two parties, the cost of landfilling and incinerating will have to decrease. They will have to establish an incentive to recover electronics products, possibly through support from the manufacturers. Recovery and collection must be less expensive than the wasteful alternatives of landfilling and incinerating. The infrastructure must also remain simple for businesses and consumers to participate. Municipalities and waste handlers will enable consumers to place their electronics waste alongside of their household trash. Retailers selling electronic products should participate by taking back used products. These products will then be sent to the local collection center or to the original manufacturer. Once collected, the waste should be sorted and disassembled locally to avoid costly storage and transportation costs. The reusable and recyclable parts can then be organized regionally for shipment to manufacturers for use in their products.

All of these efforts have to come together through the implementation of surcharges and regulations. It is imperative that a surcharge be added to the price of an electronic product. This surcharge will be used to help fund the collection, sorting, and transportation costs associated with the infrastructure. Transportation is one of the most costly aspects of the infrastructure. A national and local transportation partnership should be developed. The coordination of the transportation effort, along with the surcharge, collection and disassembly efforts, should be intelligently regulated by the federal government. Coordination
and teamwork are necessary for the infrastructure to function. Without government participation, the infrastructure will not be maintained or organized for sustainability. Regulations need to be developed for consistency across state and local governments, and to set targets or goals. Government involvement is also necessary for education of all participants to promote collection, reuse, recycling and ultimately closing the lifecycle loop.

To summarize, an **infrastructure** must be established in order to solve the problem of electronic products not being recovered, reused or recycled in the U.S. The following aspects are required:

1. **Electronics manufacturers** must conduct a product lifecycle assessment and commit to extended producer responsibility.

2. **Municipalities** and **waste handlers** are required for recovery and collection that must be less expensive than landfiling and incinerating

3. The infrastructure must remain simple for **consumers** and **businesses** to participate. Used electronics should be returned to the retailer or placed with curbside waste.
4. Once collected, the waste or products should be **sorted** and **disassembled locally** to avoid costly transportation and storage costs.

5. The reusable and recyclable parts can then be **organized regionally** for shipment to manufacturers for use in their products.

6. Transportation is one of the most costly aspects of the infrastructure. A national and local **transportation partnership** should be developed.

7. **Surcharges**, added to the price of an electronic product, need to be implemented to help fund the collection, sorting, and transportation costs.

8. **Government** involvement is necessary for maintenance and sustainability of the infrastructure.

9. **Regulations** need to be developed for consistency across state and local governments, and to set targets or goals.

10. Government involvement is also necessary for **education** of all participants to promote collection, reuse, recycling and ultimately closing the lifecycle loop.
C. Recommendations

This topic is quickly evolving. Progress towards forming partnerships and government legislation is made monthly. Recommendations for future research include continued follow-through with industry organizations; interviews with local, state and federal government agencies; and information gathering from the transportation industry, waste haulers and collection and disassembly sites. In-depth research into how the infrastructure would function would be beneficial. One example would be to explore how post-consumer products would be handled in the infrastructure, specifically, how they arrive at a collection site, how the products are processed and how the products are then returned to the manufacturers and placed back into a production line. There are many opportunities for further research since this is an evolving and dynamic concept that will surely bring challenges to the electronics industry.
V. Definition of terms

“Demanufacturing” the process opposite to manufacturing involved in recycling materials and products after a product has been taken back by a company (http://www.srl.gatech.edu/education/Recycle/Cloop.html, 1)

“Electronics industry” The electronics industry produces electronic equipment which is defined as a product or apparatus that has its primary functions provided by electronics circuitry and components. Examples include semiconductor devices such as integrated circuits, transistors and diodes; passive components such as resistors, capacitors, inductors; electro-optical components such as CRTs, LEDs, CCDs, lasers; sensors such as transducers, MEMs devices; and electronics packaging such as printed circuit boards and connectors.¹

“Electronics equipment” - There are six categories of electronics equipment. These are Commercial, Industrial, Consumer, Automotive, Aerospace and Military/Defense. This paper will focus mostly on commercial equipment such as computers with peripheral equipment and office equipment such as copiers, imaging systems and printing systems. There will also be some discussion of consumer equipment such as televisions and VCRs. (http://www.iaer.org/electronicsequipment.htm, 1)
“Post-consumer recycling” - This is the recycling of a product or material after it has been used by a customer. (http://www.srl.gatech.edu/education/Recycle/Cloop.html, 1)

“Pre-consumer recycling” - recycling of waste that occurs during the manufacture of a product. (http://www.srl.gatech.edu/education/Recycle/Cloop.html, 1)
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PATRICIA O. DONOHUE
3174 Valley Drive
Walworth, NY 14568
(315)986-5561

OBJECTIVE
To obtain an environmental engineering or health and safety position which includes responsibility for reducing costly waste streams, maintaining regulatory compliance and improving environmental and working conditions.

EDUCATION

Rochester Institute of Technology, Rochester, NY
Master of Science
Environmental, Health & Safety Management

Rochester Institute of Technology, Rochester, NY
Bachelor of Science
Environmental Management

EXPERIENCE

Xerox Corporation
Webster, NY
Environmental Engineer
1998 Present

Planning Activities:
- Support timely environmental permitting through preparation of complete and accurate permit applications for air and water compliance
- Support Title V facility air permit issuance with strategic negotiation of key permit requirements while developing a sound compliance demonstration methodology
- Communicate key permit and regulatory requirements to plant operations personnel to assure timely implementation of compliance requirements
- Interface with local, state and federal regulatory agencies and manage major compliance issues to achieve satisfactory resolution
- Ensure environmental compliance by completing accurate and timely regulatory reports such as NYSDEC Fuel Use/Industrial Process Emission Summary (Emissions Statement), annual federal air emission special condition reports, local industrial sewer use monitoring reports, State Pollutant Discharge Elimination System (SPDES) discharge monitoring reports, and annual Hazardous Waste Reduction Plan for Webster facility while providing corporate-wide support
- Support Waste Free Initiatives through 3R’s program and contribute to worldwide environmental performance report
- Provide necessary support for Customer Satisfaction/Customer First including participation in ISO 14001 audits
- Ensure financial productivity through quarterly assessments for major organizations and manage vendor invoices
- Participate as a stakeholder for the development of a new Xerox software product, “EcoWorx”, for Environmental, Health & Safety document management
- Track and interpret local, state and federal regulatory changes and determine impact on company operations and processes
Xerox Corporation, Environmental Engineer, continued

**Operations Activities:**
- Identify environmental aspects through completion of process input/output diagrams, mass balance calculations and utilization of Environmental Compliance Request Form for new projects
- Administer environmental training to enable compliance with RCRA, SPDES Best Management Plan, and Sanitary Sewer Industrial User implementation requirements
- Provide required information for environmental regulatory reports and corporate environmental reports such as SARA Tier 2 Chemical Inventory Report, SARA Tier 3 Toxic Release Inventory Report, Annual Waste Generator's Report, Annual Air Emissions Statement, Hazardous Waste Reduction Plan, Air Permit Special Conditions Reports, and Xerox Corporation's Environment, Health and Safety Annual Progress Report
- Complete plant environmental audits to identify performance improvement opportunities, participate in ISO 14001 audits and regulatory agency audits and implement corrective actions as required

**Lawler, Matusky & Skelly Engineers, LLP**
Wappingers Falls, NY

- Environmental Engineer
- 1995 - 1998

- Completed Title V and State Facility Air Permit applications for large industrial clients including IBM and Novartis Pharmaceuticals
- Determined State and Federal regulatory applicability
- Developed Facility and Emission Unit Compliance Certifications and monitoring procedures
- Completed supporting documentation including Operational Flexibility and Alternate Operating Scenarios
- Completed Environmental Impact Assessments
- Calculated and applied for Emission Reduction Credits per 6 NYCRR Part 231
- Submitted NYSDEC Fuel Use/Industrial Process Emission Summary (Emissions Statement) per 6 NYCRR Part 202-2
- Documented, sampled and managed operation of pilot wastewater treatment project
- Performed SPDES compliance tasks including sample collection, flow monitoring and measurement
- Modified Contingency Plan and Emergency Procedures plan in accordance with 6 NYCRR Part 373-3.4

**Johnson Controls, Inc., Erie Mold and Engineering**
Erie, PA

- Environmental Co-Op
- 1994 - 1995

- Assessed, quantified and documented all waste streams including solid, hazardous, air and water
- Completed governmental reporting requirements
- Produced waste reduction strategies
- Developed expense reductions for this Fortune 100 company
- Reduced hazardous waste generation
- Interpreted government regulations and guidelines
- Completed Tier Two Report
- Developed procedures for handling specific waste streams
- Designed a new Material Safety Data Sheet database system and maintenance procedures
- Implemented office and factory recycling program
- Organized existing environmental documents
- Participated in Corporate Environmental Audit
- Attended JCI Corporate Environmental Training Program
TRAINING & AWARENESS

- OSHA 8-Hour Permit-Required Confined Spaces, 29 CFR 1910.146(g)(1), Competencies: Attendant, Entrant, and Entry Supervisor
- RCRA Compliance for Generators with DOT General Awareness Training
- American Red Cross Adult CPR Certified
- American Red Cross First Aid Certified
- Attend “Annual Industry - Environment Conference” sponsored by The Business Council of New York State, Inc. in cooperation with the New York State Department of Environmental Conservation