1. Background and Problem Definition

The Team. The NJIT P3 Student Design Team consists of five Industrial and Manufacturing Engineering (IME) seniors—Javier Ortiz, Marelis Bernal, Yvette Blackbourne, Jennifer Hernandez and Fernando Albayeros—in collaboration with William Davis, an Environmental Policy graduate students. The primary faculty mentors for the team are Dr. Reggie J. Caudill (IME) and Dr. Maurie Cohen (Environmental Policy). The P3 project was integrated within the IME senior capstone design course administered by Dr. Stephen Tricamo (IME).

Problem Definition, Relevance and Significance. The volume of electronics products manufactured has increased significantly over the last several decades. Due to rapid technological innovation, computers, video and audio equipment, and communication devices quickly become outmoded, resulting in large-scale disposal or exportation to developing countries. The problem is that the constituent components of many of these electronics products contain toxic chemicals such as lead, cadmium, chromium and mercury. An earlier Environmental Protection Agency (EPA) study of products containing lead and cadmium in municipal solid waste estimated that in 1986, 24 % of all lead in the municipal waste stream was attributable to CRTs, second only to lead-acid batteries, which accounted for 65% [Ish93].

These hazardous materials need to be handled correctly otherwise they can contribute to contamination of ground water or air. The export of e-waste to China and other countries has been documented and shown to create major ecological and human health problems. The numbers associated with e-waste are staggering: in California alone, it has been estimated that 10,000 computers and televisions become obsolete every day. Furthermore, according to the 2002 consumer electronics report, over 30 million televisions and 25 million computers were sold in the US in 2001; consequently, the waste stream is growing rapidly.

According to recent articles, "Over 50% of American households own computers and we're discarding them faster and sooner…A computer's average lifespan now is only two years. By 2007, this trend will have generated 1.58 billion pounds of lead and 632,000 pounds of mercury, much of which will end up in our environment"[Cau01].

Statistics indicate that:

- Over 63 million tons of computer equipment will be taken out of service next year, and 85% of them will end up in the landfills (National Safety Council, 2001).
- Over 50% of computers being recycled are in good working order (Silicon Valley Toxics Coalition, 2001).
- 500 million computers in the world contain 6.32 billion pounds of plastic, 1.58 billion pounds of lead, and 632,000 pounds of mercury (Basel Action Network, 2002).

Clearly, this is a sustainability issue that affects the very fabric of our way of life through ever increasingly negative impacts on people, prosperity and the planet.

Fortunately, many individuals and organizations have begun to recognize this problem. Several municipalities and some states have initiated pilot collection and recycling programs, often in cooperation with major manufacturers and retailers. In the fall of 2003, California signed into law legislation known as SB-20 that establishes a statewide electronics recycling program for CRT-based products and provides financing for the collection, transportation and processing of this equipment through a front-end fee paid by the consumer at the time of product purchase. Another effort, referred to as the National Electronics Product Stewardship Initiative (NEPSI), is a multi-year effort established through the US EPA to examine issues associated with electronics recycling, engage in discussions to build consensus among all stakeholder groups, and recommend a strategy for developing a national electronics recycling program.

Relationship to P3. Electronics recycling is a classical sustainability challenge affecting people, prosperity and the planet. This section discusses how each of these elements is involved:

People. Societal concerns are inherently coupled to the e-waste issue as consumers generate demand for new products in the marketplace, households become storage areas for obsolete products on their way into the waste stream, and in one way or another, people will pay the cost associated with the recycling program. With the current political landscape, there would be minimal support from lawmakers and the general public to fund the cost of the system, regardless of its merits, by legislating new taxes. In addition, residents will be expected to initiate the collection activity by taking their old electronics to a nearby collection site or placing the equipment curbside, in the event this option was available. Although not addressed explicitly in the project, consumer behavior and their acceptance of remanufactured products and products made from recycled materials will be critical to the overall success of recycling and reuse. Currently, much of America's e-waste is being exported. This means of disposal profoundly affects people in other countries, especially developing countries. Some of the impact is positive, providing jobs and used, but still functional, equipment at lower cost; however, much of the impact is negative, dumping hazardous and toxic materials into countries with little or no institutional capacity for effective environmental protection, an unfortunate situation that exposes workers to unacceptable health risks [Cau04].

Prosperity. Economics is a key driver in the design of the system as related to costs and benefits generated. If recycling fees are low, there will be minimal negative impact on consumers' buying behavior and manufacturers will be more inclined to support the concept. The overall cost of the recycling system will depend on many factors, including the near-term capital and long-term operating costs for collection, transport and processing, as well as the selling price associated with recovered products, components and materials. In most cases, processing costs are affected by the product design; consequently, if manufacturers internalize the recycling cost, then additional economic drivers will encourage companies to design future products with full consideration of recyclability and reuse. Furthermore, the national recycling system should provide sufficient quantities of recycled materials at low costs so that manufacturers can reliably and economically increase the percentage of recycled content in their products [Cau04].

The Planet. A national electronics recycling program has the potential to divert materials from being land filled and to convert them into useful feed stocks for new products. Within the framework of a national system, the opportunity exists to achieve several material and resource conservation goals: to close material loops, to conserve energy and other natural resources, and to extend product lifecycles. Mapping these goals into environmental impacts suggests that the project has the potential to reduce greenhouse gas emissions, acidification, euthrophication, photochemical smog, and material/resource depletion. Furthermore, if recycling is not implemented, land fills will need to be expanded to accommodate the growing volume of waste electronics, and the potential for leaching may contaminate ground water, creating an even bigger environmental problem in the future [Cau04].

2. Purpose, Objectives, and Scope

The overall goal of the project is to create a national electronics recycling program that diverts materials from landfills and recycles useful materials for new products. This initial project is to develop a better understanding of viable collection, transportation and processing alternatives appropriate for electronics recycling and to estimate the scope and boundaries associated with implementing a national infrastructure. The material and resource conservations goals are to close material loops, conserve energy and other natural resources, and extend product lifecycles; while, the specific environmental goals are to reduce greenhouse gas emissions, toxic material releases, and material/resource utilization. The potential consequences of not devising a national electronics recycling program include the need to expand landfills to accommodate the increasing volume of outmoded electronics and the contamination of the ground water that will likely lead to long-term and costly remediation.

The overall objective of the project is to design a system for electronics recycling that is cost effective, operationally efficient, and operates in an environmentally safe manner. The specific objectives for this initial phase I effort are as follows:

- To review and expand previous electronics recycling system analysis tools and examine alternative collection and recycling scenarios for Essex County, New Jersey.
- To create design scale-up, economic intensity and environmental factors and drivers to scope a national electronics recycling system.
- To apply design factors to the national level in order to understand the scope and dimension of the problem for further detailed design and analysis.

3. Data, Results, and Findings

This initial project examined previous work on design and operation of electronics recycling systems including pilot programs in Minnesota, Massachusetts and elsewhere [NERC reports] and the Seattle-Tacoma study [Cau03A, Cau04]. Table 1 gives the assume characteristics of the discarded products associated with the residential e-waste stream. This data is used throughout this initial design phase to define quantities and product distributions collected and processed.

Table 1 – Discarded Electronics Waste Stream Profile

Product Type	Percent by Quantity	Avg Weight (lb) [NCA99]	% Composition		
			Metal	Plastic	Glass
Computers	30	30	70	30	-
Monitors	25	30	20	15	65
Televisions	25	50	20	15	65
Other Equip	20	25	67	33	-

In order to better understand how to design an electronics recycling system, the P3 Student Team created and evaluated alternative collection scenarios for Essex County, New Jersey. Figure 1 is a map showing the geographic boundary of the case study county, the location of Newark and other cities, and the three service areas established for the county. Figure 2 shows the population density across the county.

According to the most recent census data, Essex County's 1999 population was approximately 800,000 people. Based upon data from Minnesota and Massachusetts, e-waste is generated at a per capita rate of approximately 2 pounds per year; consequently, Essex County households are expected to generate 1.6 million pounds of discarded electronics each year. Collection options assumed for this scenario are stand-alone drop-off sites, a combination drop-off and demanufacturing site, and residential curb-side pick-up.

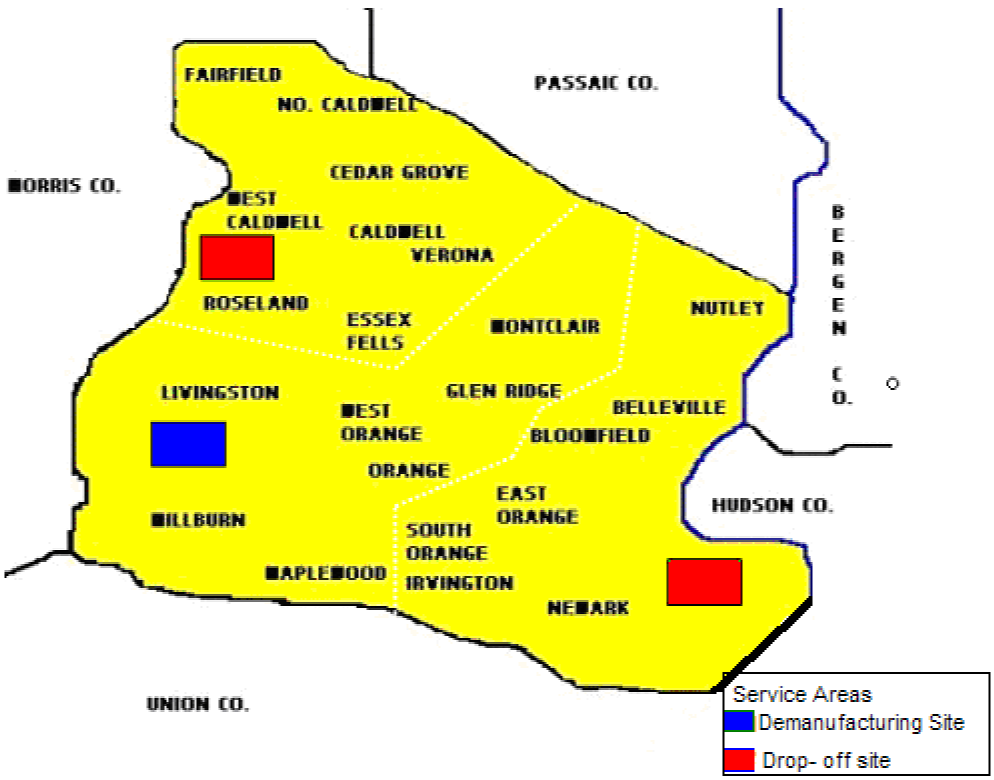

Figure 1 – Map of Essex County, New Jersey

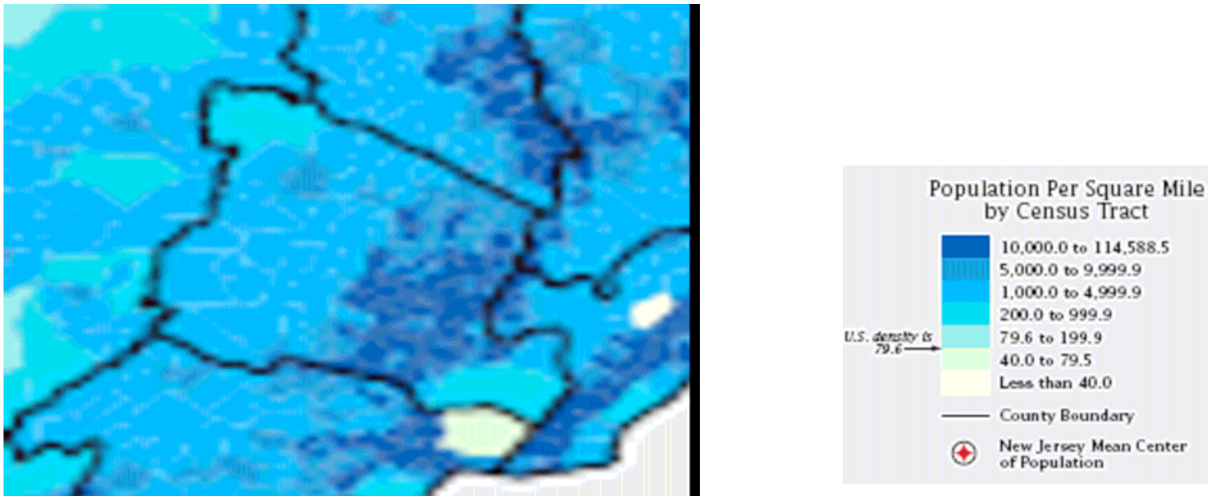

Figure 2 – Population Density Map for Essex County, New Jersey

Scenario Description. A drop off site is a location where a resident can deposit or bring any item he or she no longer uses as a donation. The actual processing plan is shown in Figure 3 below:

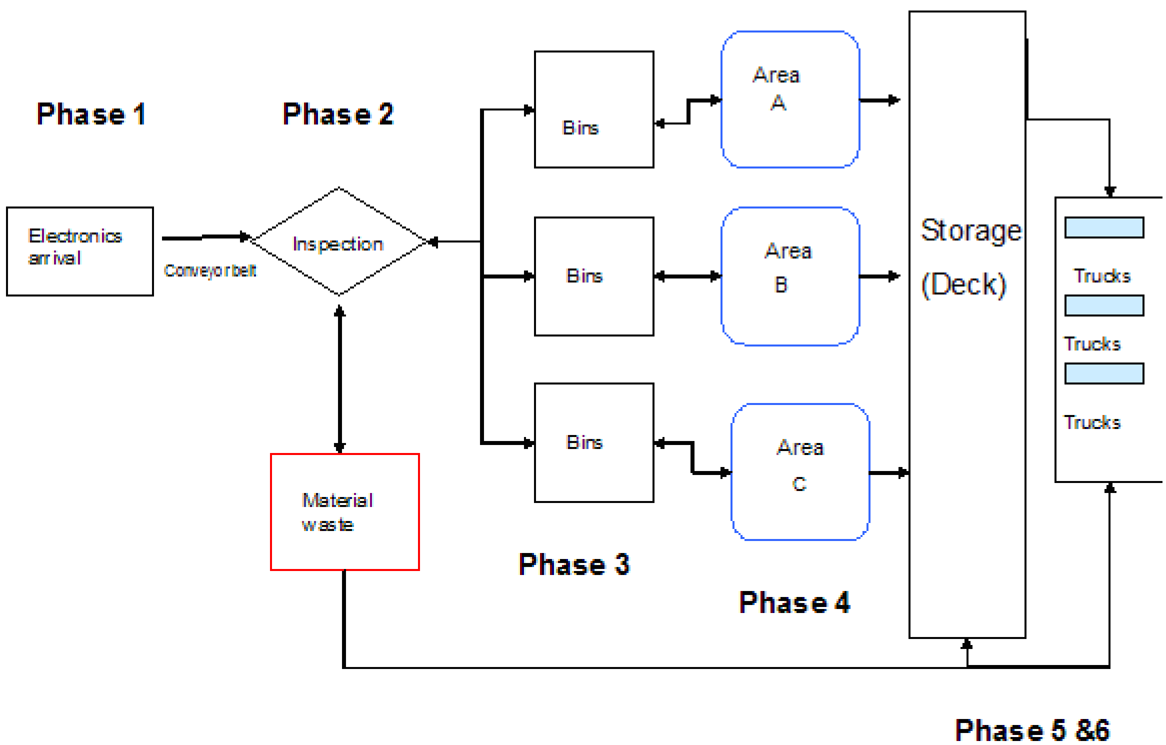

Figure 3 – Collection Drop-Off Site Operational Flow

Once electronics are dropped off they will be visually inspected and sorted. During inspection the employees will check to see if the product may be reused. If the material cannot be reused, it will be placed in bins that will be sent to a demanufacturing site. The discarded equipment that has value will be sorted out into bins which are then going to be transported by forklifts into different rooms:

Area A — Computer monitors and TVs
Area B — PC's and laptops
Area C — For all other equipment

These storage areas are actually formed by adjustable and demountable walls. Once all of the electronics are sorted out they will then be placed into the trucks and then transported to the de-manufacturing site where they will be processed.

The drop off site will have a size range between 1400-1600 square feet. The size of the facility depends on the volume of e-waste expected for the service area. The number of employees also depends on the size of the site and the volume of material collected. A demanufacturing drop off site would follow the same process as the drop off site except the facility's size is doubled or tripled to accommodate the machinery. This demanufacturing drop off site will be responsible for the disassembly of products and sorting into basic materials: metals, CRT's, plastics and printed circuit boards. CRT's would then be sent to a specialized facility for further processing.

The third collection option would be curb-side pick-up which is similar to existing recycling/solid waste handling. The trucks will pick up electronic waste from residential areas on a monthly basis. The same scheduling route of waste management systems can be used if authorized.

Advance Recovery, a demanufacturing processing company in Newark, NJ, provided some general operational and staffing data that led to our calculations regarding the number of employees per site. Based on this information and the operational requirements for the facilities, the following staffing requirements are anticipated:

- Drop-off Sites Attendants: 2 FTE
- Demanufacturing Staff: 5 FTE
- Operations Manager: 1 FTE

In addition, special collection parking lot events can be scheduled in conjunction with local retailers, shopping centers or schools. Typically, a two-day parking lot event may be set up to handle two cars simultaneously staffed with a supervisor, forklift operator and 4 helpers. This level of operation is assumed to capture two truckloads (40,000 lb) of equipment [McC03].

Scenario Cost Model and Results. The cost methodology developed for the Seattle-Tacoma study was expanded to include curbside collection options, directly estimated processing costs, and an update to the unit cost values. Figure 4 shows the Excel application sheets related to the Essex County case study.

Variable Operational Costs

Material Handling						
Truck Loading Costs						*Cost Per Pound*
Loading Rate (Gaylord/hr)	30	Labor Cost/hr	$	75.00		$0.004
Gaylord Boxes Trip-life	4	Initial cost each	$	13.46	$	
Max. capacity each (lbs)	556	Actual cost each	$	3.37		$0.006
Pallets Trip-life	4	Initial cost each	$	9.00		
Pallets per gaylord box	1	Actual cost each	$	2.25	$	$0.004
	Material Handling Subtotal:				$	$0.015
Transportation						
Factors			*Cost Per Mile*			*Cost Per Pound*
Load factor	0.32		$	2.5	$	$0.047
Distance	120					
Max. capacity of each trailer (lbs)	20,000		*Transportation Subtotal:*		$	$0.047
Volume						
Service Area Population		*Pounds Per Person*				*Total Volume (lbs)*
800,000		2				1,600,000

Total Annual Variable Operational Costs: $ **98,353**

Capital Investment Costs

Equipment							
		Costs Per Unit		*Number of Units*		*Total Costs*	*Annual Cost*
Cost of each forklift?	$	23,000	Number of forklifts?	2	$	46,000	6,250
Cost of each pallet jack?	$	346	Number of pallet jacks?	2	$	692	94
			Equipment Subtotal:		$	46,692	6,344
	Factor calculating amortized cost?			7			
			Capital Investments Total:		$	46,692	

			Total Annual Capital Investment Costs:	$	**6,344**
Fixed Operational Costs	**Labor**				
	Staff		*Wages*		*Annual Cost*
	Operations Manager	$	42,025	$	42,025
	Demanufacturer	$	24,300	$	72,900
	Helper/sorter	$	24,300	$	97,200
				$	212,125
	Fringe Benefits				
	% of total wages?		25		
			Fringe Benefits Subtotal:	$	53,031
			Total Annual Labor Costs	$	265,156
	Facility and Equipment				
	Facility		*Costs Per Unit*		*Annual Cost*
	Utilities	$	0.9	$	8,700
	Maintenance	$	248	$	248
	Dumpster	$	460	$	460
	Lease	$	0.47	$	54,522
	Equipment				
	Lease	$	0	$	0
	Maintenance	$	377	$	377
			Facility & Equip Subtotal:	$	64,307
Fixed Operational Costs	**Administrative**				
			Wages		*Annual Cost*
	Operations & Support - % of total labor + fringes?		25	$	66,289
			Costs Per Unit		
	Publicity	$	0	$	0
				$	66,289
	Total Annual Fixed Operational Costs:			$	**395,752**

Total Annual Costs	
Capital Investments:	6,344
Operational Fixed Costs:	395,752
Operational Variable Costs:	98,353
Total:	**500,449**
***Cost per lb* $/lb**	**0.313**

Figure 4 – Cost Model for Essex County Case Study

Overall recycling costs can be divided into several constituent components: collection, transportation, and processing. By analyzing these costs in depth, a range of detailed information was defined: location of each facility, volume of waste collected, population of each service area, transportation costs, labor costs, facility operations, various equipment costs, material handling, and administrative costs. Transportation cost values include the accepted distance to where the electronic wastes are sent and whether it is an isolated place or a central processing unit facility.

The cost per pound is important in determining the operational efficiency of a facility. The average cost per pound is calculated by taking the total cost of investments, operational fixed costs, and operational variable costs (totaling to $500,449) and divide by the volume of material collected and processed (totaling 1,600,000 pounds). For this case study, the cost per pound is $0.31, which is close to other estimates [Cau02] and slightly lower than the costs estimated in the California study [Boi03].

In addition, the Essex County study shows that approximately 800,000 people can be served with 3 collection sites; consequently, a reasonably efficient service area for each site is 260,000-270,000 people.

Below is a classification of the kind of collection options to apply to low, intermediate, and high density areas based on the population per square mile of Essex County:

Low density — Use parking lot events and/or drop off sites (200-1000 persons per square mile)

Intermediate density — Use big electronics retailer stores and drop off sites which includes demanufacturing sites (1,000-10,000 persons per square mile)

High density — Truck curbside pickup owner operations every 2 weeks
(greater than 10,000 persons per square mile)

4. Discussion, Conclusions, and Recommendations

The results from the Essex County have been extrapolated to the national level in order to get an estimate of the required infrastructure and costs for a national electronics recycling program. Table 2 gives the results of this analysis in terms of number of collection sites needed, volume of equipment recycled, and costs for each state. As seen over 570 million pounds (285,000 tons) of old electronics will be collected and processed each year nationally. For the estimated $0.31 per pound, this corresponds to a total cost of over $175 million annually.

Table 2. Analysis Results Table for National Electronics Recycling System

States	Population (Ppl)	Waste Factor (Ppl *	Rounded	Cost $0.31 /LB *	Rounded	LBS/Week	# of Drop-off
California	33,871,648	67,743,296	68,000,000	21,080,000	$21,000,000	1360000	136
Nevada	1,998,257	3,996,514	4,000,000	1,240,000	1,200,000	80000	8
Arizona	5,130,632	10,261,264	10,000,000	3,100,000	3,200,000	200000	20
Utah	2,233,169	4,466,338	4,000,000	1,240,000	1,400,000	80000	8
Colorado	4,301,261	8,602,522	9,000,000	2,790,000	2,700,000	180000	18
New Mexico	1,819,046	3,638,092	4,000,000	1,240,000	1,100,000	80000	8
Washington	5,894,121	11,788,242	12,000,000	3,720,000	3,600,000	240000	24
Oregon	3,421,399	6,842,798	7,000,000	2,170,000	2,100,000	140000	14
Idaho	1,293,953	2,587,906	3,000,000	930,000	800,000	60000	6
Texas	20,851,820	41,703,640	42,000,000	13,020,000	13,000,000	840000	84
Kansas	2,688,418	5,376,836	5,000,000	1,550,000	1,700,000	100000	10
Arkansas	2,673,400	5,346,800	5,000,000	1,550,000	1,600,000	100000	10
Louisiana	4,468,976	8,937,952	9,000,000	2,790,000	2,800,000	180000	18
Oklahoma	3,450,654	6,901,308	7,000,000	2,170,000	2,100,000	140000	14
Missouri	5,595,211	11,190,422	11,000,000	3,410,000	3,400,000	220000	22
Missippippi	2,844,658	5,689,316	6,000,000	1,860,000	1,800,000	120000	12
Alabama	4,447,100	8,894,200	9,000,000	2,790,000	2,700,000	180000	18
Georgia	8,186,453	16,372,906	16,000,000	4,960,000	5,100,000	320000	32
Tennessee	5,689,283	11,378,566	11,000,000	3,410,000	3,500,000	220000	22
Kentucky	4,041,769	8,083,538	8,000,000	2,480,000	2,500,000	160000	16
Virginia	7,078,515	14,157,030	14,000,000	4,340,000	4,400,000	280000	28
North Carolina	8,049,313	16,098,626	16,000,000	4,960,000	5,000,000	320000	32
South Carolina	4,042,012	8,084,024	8,000,000	2,480,000	2,500,000	160000	16
Georgia	8,186,453	16,372,906	16,000,000	4,960,000	5,100,000	320000	32
Florida	15,982,378	31,964,756	32,000,000	9,920,000	10,000,000	640000	64
W. Virginia	1,808,344	3,616,688	4,000,000	1,240,000	1,100,000	80000	8
New York	18,376,467	36,752,934	37,000,000	11,470,000	11,400,000	740000	74
New Jersey	8,414,330	16,828,660	17,000,000	5,270,000	5,220,000	340000	34
Delaware	783,600	1,567,200	2,000,000	620,000	500,000	40000	4
Maryland	5,296,486	10,592,972	11,000,000	3,410,000	3,300,000	220000	22
DC	572,059	1,144,118	1,000,000	310,000	400,000	20000	2
Rhode Island	404,424	808,848	1,000,000	310,000	200,000	20000	2
Massachussetts	6,349,097	12,698,194	13,000,000	4,030,000	4,000,000	260000	26
New Hampshre	1,235,786	2,471,572	2,000,000	620,000	800,000	40000	4
Maine	1,274,923	2,549,846	3,000,000	930,000	800,000	60000	6
Vermont	608,827	1,217,654	1,000,000	310,000	400,000	20000	2
Michingan	9,938,444	19,876,888	20,000,000	6,200,000	6,200,000	400000	40
Ohio	13,353,140	26,706,280	27,000,000	8,370,000	8,300,000	540000	54
Pennsylvania	12,281,054	24,562,108	25,000,000	7,750,000	7,600,000	500000	50
Illinois	12,419,293	24,838,586	25,000,000	7,750,000	7,700,000	500000	50
Indiana	6,080,485	12,160,970	12,000,000	3,720,000	3,800,000	240000	24
Montana	902,195	1,804,390	2,000,000	620,000	600,000	40000	4
Wyoming	493,782	987,564	1,000,000	310,000	300,000	20000	2
North Dakota	642,000	1,284,000	1,000,000	310,000	400,000	20000	2
South Dakota	754,000	1,508,000	2,000,000	620,000	500,000	40000	4
Nebraska	1,711,263	3,422,526	3,000,000	930,000	1,100,000	60000	6
Iowa	2,926,324	5,852,648	6,000,000	1,860,000	1,800,000	120000	12
Wisconsin	5,363,675	10,727,350	11,000,000	3,410,000	3,300,000	220000	22
Minnesota	4,919,479	9,838,958	10,000,000	3,100,000	3,000,000	200000	20
	285,149,376	**570,298,752**	**573,000,000**	**177,630,000**	**177,020,000**	**11,460,000**	**1,146**

The US was divided into six geographic regions each assumed to setup and operate a single CRT-glass processor. The color coded map shown below in Figure 5 defines the six regions.

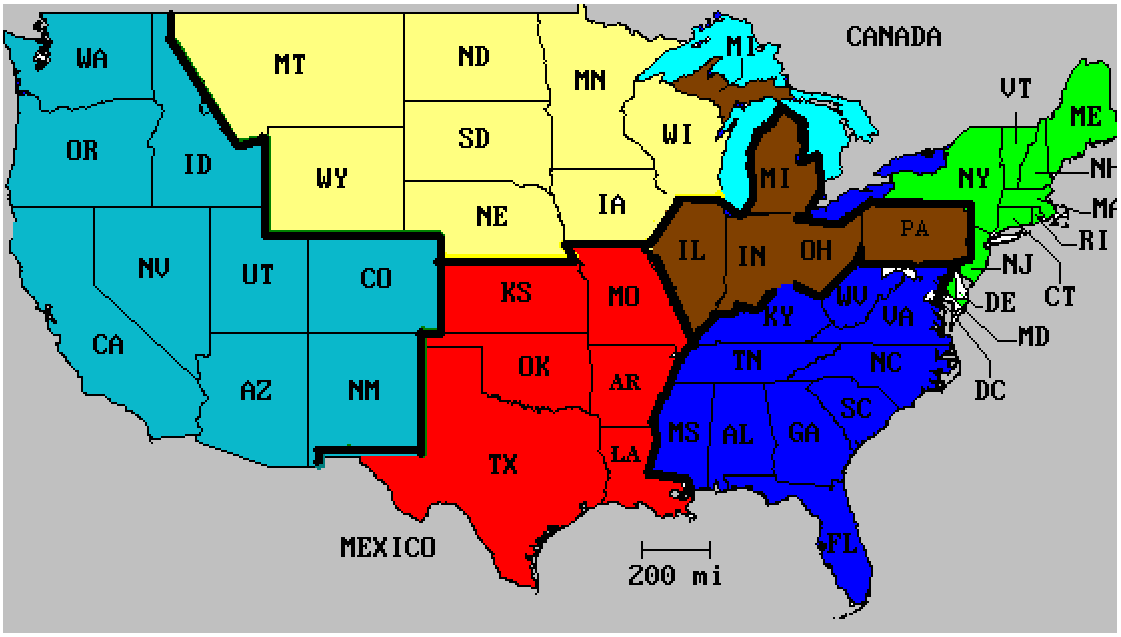

Figure 5 – National Regions for Study

Table 3 shows the results of the study for each region, including regional population, volume of discarded electronics recycled, number of collection sites, and costs.

Table 3. Summary of National Level Results by Geographic Region

Regions	Population	Volume of e-waste (lbs)	Cost ($)	No. of Drop off sites
1	59,963,486	119,926,972	37,510,000	242
2	39,728,479	79,456,958	24,490,000	158
3	70,356,278	140,712,556	43,400,000	280
4	43,315,999	86,631,998	27,280,000	176
5	54,072,416	108,144,832	33,790,000	218
6	17,712,718	35,425,436	11,160,000	72
Total	**285,149,376**	**570,298,752**	**177,630,000**	**1146**

Benefits to People, Prosperity and the Planet. Societal concerns are inherently coupled to the e-waste issue as consumers generate demand for new products in the marketplace, households become storage areas for obsolete products on their way into the waste stream, and in one way or another, people will pay the cost associated with the recycling program. In this study the focus is on economic implications and environmental concerns.

Diverting electronics from land-fill. With a national electronics recycling system in place, over 570,000,000 of old electronics will be diverted from the land fill.

Reducing the amount of lead and other hazardous materials from landfills. The project's impact can be quantified in terms of reduced environmental impact and/or in terms of improved environmental health. The amount of lead and mercury from Cathode Ray Tubes (CRT's) was estimated. These results are shown in Figures 6 and 7, respectively. Based on collection data from Minnesota and the assumed characteristics of the e-waste stream in Table 1, the amount of lead (Pb) and mercury (Hg) in each computer is 3.16 lbs and .00126 lbs, respectively. [Cau01]

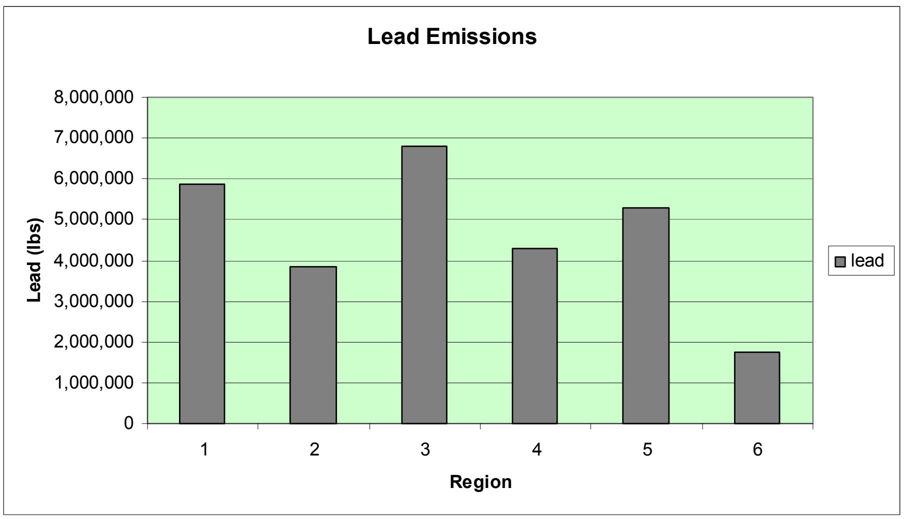

Figure 6 – Estimate of the Amount of Lead Diverted from the Land Fill

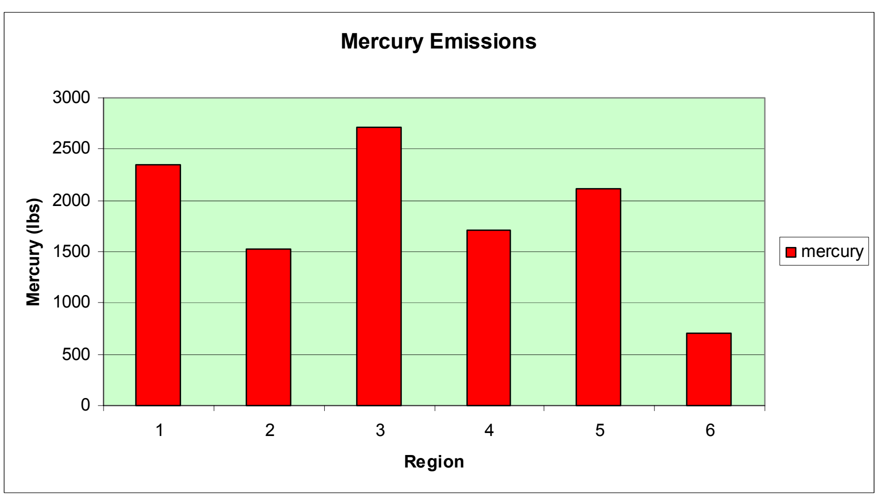

Figure 7 – Estimate of the Amount of Mercury Diverted from the Land Fill

Proposal for Phase II

The NJIT team is not requesting funding for Phase II; however, the team believes its initial phase was extremely successful in identifying the scope and boundaries to the design problem proposed. Consequently, the NJIT Student Design Team deserves full consideration for the P3 student design competition. The following describes some thoughts as to how to proceed with a detailed design and implementation for a National Electronics Product Reuse and Recycling System.

Major Tasks. The primary tasks to finalize the design and analysis of a national electronics product reuse and recycling system are described below. Each of these tasks involves research to better understand the P3 implication in each area, to select appropriate analysis tools and techniques, and collect data to support the design and analysis process; development activities to adapt this knowledge and information to the P3 design challenges for the system; and, implementation efforts to assure the final design achieves success from all perspectives including technical soundness, economic viability, and full stakeholder acceptability.

1. <u>Infrastructure and Operational Scenario Builder</u>: Various collection scenarios will be considered for the case study area ranging from single, large drop-off facilities to a highly-distributed set of micro-collection facilities co-located at existing retailers, charities and municipal facilities. In addition to fixed drop-off facilities, some of the scenarios may include special collection events at parking lots and other locations in the study area. Consideration of other infrastructure elements, e.g., consolidation points, transportation strategies and processor locations, and potential policy implications will be included.

2. <u>Service Area and Collection Volume Estimator</u>: Population databases (e.g., Census 2000) may be used in conjunction with the area highway network to map locations, determine population and the number of households within the service areas and calculate travel and transport distances. For each collection site in a scenario, an estimate of e-waste expected to be collected will be determined from which the facility and operational requirements and associated costs can then be calculated. Various approaches to forecasting product obsolescence and estimating e-waste generation will need to be explored by the design team.

3. <u>Material Flows and Operations Simulation</u>: A discrete event product/vehicle flow simulation may be useful in depicting process delays, designing facilities and estimating vehicle queuing at system collection sites. From these calculations and other operational and facility data, the energy consumption and greenhouse gas impact of each scenario can then be estimated.

4. <u>Collection, Transportation, Consolidation and Processing Cost Model</u>: A set of cost models will need to be developed that directly estimate capital costs, operational fixed costs and operational variable costs. With these general models, the incremental and marginal costs for providing electronics collection at existing facilities or newly constructed facilities can be determined. Cost drivers can be determined and linked to operational and convenience factors leading to opportunities for cost reduction and operational improvements.

5. Financing Strategies and Policy Implications: Various options for financing the system, ranging from advanced recovery fees paid by the customer at the time of purchase to end-of-life fees paid at the time the product is dropped off at a collection site, should be explored. Each alternative has significant policy implications from both an environmental and societal perspective, as well as a political perspective that must be understood and evaluated.
6. Design Criteria Evaluation and Assessment of Sustainability: Evaluation of design criteria related to cost, efficiency, effectiveness, convenience, environmental soundness and sustainability, and flexibility will be used to assess each scenario. Program design is an iterative process in which lessons learned and analysis results from other scenarios can be used to modify designs and improve the balance between the design criteria.

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