Electronic Waste Recycling Programs in the United States:

A Comparative Analysis

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Abstract

Proper recycling of electronic waste (e-waste) allows reuse of finite resources and prevents toxic materials in e-waste from causing harm to humans and the environment. The United States is the only, Organization for Economic Co-operation and Development (OECD) country without national e-waste recycling policies. Currently, 25 States have e-waste recycling policies, and 19 impose landfill disposal bans. Without federal regulations, laws differ from state-to-state, making it difficult to control and measure outcomes. This analysis applies a framework to compare three different types of state e-waste policy program models including: 1) Extended Producer Responsibility (EPR); 2) Consumer-based Advanced Recovery Fee (ARF); and an 3) electronic recycling education program. Program success was measured by the amount of e-waste recycled by weight and product category per capita (volume); the number of permanent collection sites; the number of collection events; who bares the costs (convenience); and if rewards or penalties are established, (incentives) to encourage recycling. This analysis suggests convenience, cost and incentives are the main contributing factors to program success and increasing recycling volumes. This analysis also identifies the need for consistent reporting of e-waste data in all states to provide greater transparency, and more accurate and consistent data regarding the amount of e-waste recycled. Furthermore, policies at the federal level are needed to address trans-boundary movement of e-waste across state lines.

KEY WORDS: comparative analysis, electronic waste, e-waste, e-waste policies, program evaluation

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Introduction

Electronic waste (e-waste) is one of the fastest growing solid wastes streams in the United States. In 2012, over 426 million units of electronics were purchased by U.S. consumers, which was 17 percent of all electronics produced worldwide. This was an increase of 84.8 million units in two years. Most American households have an average of 24 electronic devices, with the average lifecycle, including primary and secondary users, being 5 to 13 years (U.S. EPA, 2014b, p. 61). In 2000, 1.9 million tons of e-waste was generated, and only 10 percent was recycled. By 2012, the amount of e-waste generated increased to 3.4 million tons with 29 percent recycled. What happens to the rest? If e-waste is not recycled, it is stockpiled, put in landfills, incinerated or exported to developing countries (ETBC, 2013b). All of these alternatives can lead to negative impacts on human health and the environment.

Electronics contain valuable finite resources such as: copper, gold, aluminum and rare earth minerals. Failing to retrieve and reuse these resources leads to an increase in demand for mining raw minerals from the earth. Mining causes a negative impact on the environment due to the high volumes of waste it produces, and the intense energy required to extract the metals from ore. For example, to produce one ton of aluminum, 20 to 30 tons of ore is dumped as waste. Additionally, the smelting and processing of all these materials releases carbon dioxide into the atmosphere and contributes to the increase of greenhouse gases (Rainforest Relief, 2014).

When e-waste is put in a landfill, not only are finite resources lost, but there is risk of toxic material leaching overtime and contaminating soil and ground water. Globally, many

electronics are recognized as hazardous electronic waste (HEW). These HEWs include metals such as: lead, mercury, cadmium, beryllium and other problematic components such as: polyvinyl chloride (PVC) and brominated flame retardants (BFRs), which are carcinogenic when incinerated. Heavy metal exposure can lead to acute symptoms such as coughs, nausea and headaches (see Appendix A), as well as serious chronic conditions including: neuropathy, cancer and death (CDC, 2013).

Estimates indicate more than 50 percent of toxic e-waste, not recycled in the U.S., is illegally transported to developing countries, including: Africa, China and India, to be recycled in primitive recycling villages (ETBC, 2011). In places like, Guiyu, China, poor people earning less than 20 U.S. dollars per day, break down hazardous electronics to extract the valuable finite resources, exposing themselves and their children to hazardous heavy metals, which also leach into ground water contaminating wells and nearby rivers (The Wasteland, 2008).

In 1989, at a United Nations conference in Basel Switzerland, global inequity of hazardous waste was addressed when 179 countries, including the U.S. signed a treaty stating no hazardous waste would be exported from developed nations to developing nations. By 1992, all of the countries accept for Afghanistan, Haiti and the U.S. ratified the Basel Treaty into law (Basel, 2013). Not only has the U.S. still not ratified the Basel Treaty, but there are minimal e-waste policies, which only pertain to Cathode Ray Tubes[1] (CTRs) (U.S. EPA, 2013).

Without federal regulations, it is left to each state to create policies, generate funds and manage programs (U.S.EPA, 2014b). Currently, 25 U.S. States have some type of e-waste policy, and 19 have banned hazardous e-waste from being put in solid waste landfills (see Appendix B). Because states don't currently prevent hazardous e-waste from crossing state

lines, or regulate international exports of e-waste, how successful are these policies? For instance, what prevents hazardous CRTs full of lead from being transported to landfills in one of the 31 states with no regulations against putting e-waste in a landfill (ERCC, 2013)?

Stone Castle Recycling in Parowan, Utah, USA, is an example of what can happen when policies are not good enough. Stone Castle had been collecting e-waste to "recycle", but instead stockpiled large amounts outside their facility. On March 3, 2014, over 300 cardboard *Gaylord* boxes (4 x 4 cubic feet) full of old console TVs, CRT monitors and other electronics, turned into a toxic inferno. The fire released carcinogenic chemicals into the atmosphere, and left residual heavy metals on the ground (BAN, 2014). Stone Castle is a recycler listed on Utah's Department of Environmental Quality website (Utah DEQ, 2014).

Inconsistent state policies or lack of policies, lead to inadequate reporting and control of e-waste. This analysis set out to identify best practices to inform states how to overcome challenges, and develop optimal program infrastructures to eliminate putting e-waste in landfills, incinerators, using prison labor or illegal export.

Five programs were evaluated to determine how much e-waste was recycled per capita. It was then compared to the number of collection sites and events, as well as if there were incentives (penalties or rewards) to recycle. Discovering best practices, to encourage reuse and recycling of covered electronic devices (CEDs) domestically, may lead to less e-waste lost to landfills or illegal export (ERCC, 2010).

This analysis compares the three types of state e-waste policies in the U.S. including: 1) Consumer-based Advanced Recovery Fee (ARF) system, which requires consumers to pay for future recycling costs at point-of sale (Calrecycle, 2014a); 2*)* Extended Producer Responsibility (EPR), which places the burden on the manufacturer to cover costs to recycle CEDs at end-of-

life; and 3) Utah's electronic recycling education program, that requires manufactures to provide consumer education about where and how to properly recycle CEDs (Utah DEQ, 2013). State recycling programs differ in multiple ways, such as: 1) which electronic products are included in the program; 2) which entities are covered (e.g. households, businesses etc…); 3) who pays for the recycling; and 4) what documentation is required and how is it reported.

The two main questions of this analysis are: 1) What policies have been developed in the U.S. to divert e-waste from landfills, incinerators and illegal export to and enable reuse of finite materials?; and 2) How effective are these state policies? To address these questions, this analysis compared rules that involved CEDs in each program; rules for program "actors"; and rules that regulate e-waste disposal and recycling processes.

The subsequent sections of this paper are organized as follows. First, relevant papers from recycling literature are reviewed to justify analysis framework and modeling choices. Next, there is a review of datasets and methodology. Then, the analytical framework and research design are discussed. Finally, the results, conclusions and suggestions for future work are shared.

Literature Review

Recycling electronics effectively is a challenge facing the U.S, and currently the burden is on each individual state. A number of articles and studies discuss the problems with e-waste, and challenges the recycling industry stakeholder's face. There are several articles that analyze recycling policies and best practices within North America and Europe. The Extended Producer Responsibility (EPR) is the most common program model; therefore multiple articles have been reviewed on that topic.

Problems with E-waste

E-waste is a growing problem, (Bhutta, M.K.S, et al., 2011) as the volume increases, so does the toxic waste. The absence of federal policies in the U.S., and non-cohesive state policies, has led to more e-waste being dumped in solid waste landfills or being exported illegally. Planned obsolescence, which is designing electronic devices to wear out quicker, magnifies the e-waste problem (Meigs, 2012).

The Federal EPA concurs; e-waste is a global problem that negatively impacts human health and the environmental and exporting e-waste is a "lost opportunity to recover valuable resources" (Adrian, 2013). However, simply acknowledging the issue fails, to prevent illegal exports of hazardous e-waste from shipping to developing countries or being dumped in landfills (Adrian, 2013).

In an EPA report, Daniel Gallo shared the EPAs role in e-waste management, it included the following: 1) creating incentives for greener products; 2) federal government to lead by example; 3) placing emphasis on safe and effective management of e-waste in the U.S.; and 4) U.S. to reduce harm from exports of e-waste to developing countries (Gallo, 2013, p 16).

E-Waste Industry Challenges

It's problematic for manufactures to create and maintain take-back programs that are in alignment with all of the different state policies (Greenemeir, 2009). A factor challenging state e-waste policies, is the potential impact neighboring states without policies may have, especially in regards to landfilling electronics that are difficult and costly to recycle (Bhutta, M.K.S., et al.,2011). When costs to recycle electronics meet or surpass the material value, motivation to recycle decreases. This challenge was addressed by Milovantseva and Saphores (2013a) in their study that explored preferences of U.S. households for disposing of their e-waste. They surveyed 3,159 respondents, using a multinomial logit model, to find out what consumers did with

electronics when landfill bans were imposed. The category options included: “Recycle”, “Trash”, “Reuse” and “Store.” They suggested consumers were more likely to “recycle” smaller devices, such as mobile phones, and “store” larger items, such as televisions, when there was a ban on putting electronics in landfills. They also suggested convenience was a factor, as it is easier to store a TV, versus hauling it to a recycler, and possibly having to pay a fee to recycle it.

In contrast, the Electronics Take Back Coalition (ETBC,2011) has found landfill bans lead to an increase in e-waste recycling in most states. For instance, in January, 2006 Maine started an e-waste recycling program and collected 1,292,202 pounds of e-waste in six months. After the landfill ban went into effect on July 1, 2006, the amount of e-waste collected in the next six months, more than doubled at 2,869,372 pounds (ETBC, 2011).

Policies and Best Practices

A study conducted at the Georgia Institute of Technology showed individual producer responsibility, (IPR) versus collective producer responsibility, (CPR) was more effective at creating an incentive for producers to manufacturer products that last longer, are easier to recycle and are less toxic. The CPR models are based on manufactures paying a percent of all electronics sold, regardless of brand. This creates a “free-rider” situation, because product types are not differentiated, and companies that produce electronics that reach end of life sooner, and are more costly to recycle, benefit from producers that are making their products last longer and are less costly to recycle (Atasu and Subramanian, 2012).

The Electronics Recycling Coordination Clearing house (ERCC) collaborated with the Product Stewardship Institute, (PSI) and multiple recycling industry stakeholders, to identify performance measures to compare e-waste programs (ERCC, 2010).

Producer Responsibility

Many papers explore Extended Producer Responsibility (EPR), because it is a common model. Characteristics of EPRs include: manufacturers are responsible for the cost of recycling e-waste; manufacturers are required to organize collection sites and events; annual recycling quotas for manufacturers must be met; and there are often penalties for short falls. Kiddee's study suggests EPR may not be adequate alone, but when combined with other tools (e.g. Lifecycle Assessment, Material Flow Analysis and Multi Criteria Analysis) many issue may be resolved. Kiddee also suggested limited federal involvement in state policies contributes to limited abilities to effectively recover e-waste in take-back programs (Kiddee, 2013).

Nash and Boso's key finding showed EPR models create conflicts between producers and waste collectors, because producers are only obligated to ensure end-of-life electronics are recycled, and generally have no incentive to encourage production of less toxic, or easier to recycle electronics (Nash and Boso, 2013). Mayor and Butler (2013) found EPR models often lead to negative behaviors such as stockpiling of e-waste, because collectors and processors are required to accept all CEDS when registered in the program. There can be an unequal distribution of devices, which vary in levels of toxicity and complexity to recycle. Since reimbursements are based on CEDs weight and not type, it can put some processors at a disadvantage.

Competition in the U.S. market inhibits cooperation between brand owners regarding collective take-back programs (Hickle, 2013). Hickle suggests some companies are "free riders" and are not fulfilling their financial obligations. The e-waste programs need to emphasis recycling goals, standards that focus on consumer convenience for collecting CEDs, and impose enforcement mechanisms to decrease the number of "free riders." Atasu and Subramanian (2011) had similar findings with collective product return programs. They found, because some

manufacturers would benefit from others, it would demotivate other companies and prevent them from reaching or surpassing their recycling goals.

Methodology

To evaluate the five e-waste recycling programs, Calrecycle, E-Cycle, E-Cycle Oregon, E-Cycle Washington, E-Cycle Wisconsin and Utah, the comparative analysis research design was based on Robert Yin's (2014) methodology. Following Yin's method, the first step was to identify similarities and differences in programs. The goal was to analyses a few programs that would be representative of all 25 state programs. The next step was to create a strategy with a matrix of categories and place program attributes into the categories. This was followed by creating tables to examine information and identify available data. Finally, by working with the data from the ground up, as directed by Yin, patterns were identified (Yin, 2014 p. 133-137). The data was then compared to established performance measures used in other analysis.

Data used in this analysis came from governmental agencies and regulators, including: the California State EPA and the Calrecycle Program (Calrecycle.2014a); the Washington State Department of Ecology and the E-Cycle Washington Program (E-Cycle Washington, 2013); the Wisconsin's Department of Natural Resources (WI- DNR, 2013) and the E-Cycle Wisconsin Program; the United States Environmental Protection Agency (U.S. EPA, 2014a); the Utah Department of Environmental Quality (Utah DEQ, 2014); the Databases from Electronics Recycling Cooperation Clearinghouse, (ERCC, 2013); the Electronic Take Back Coalition (ETBC, 2013a), and the National Center for Manufacturing Sciences (NCMS, 2013).

Best practices for measuring performance, and comparing state electronic recycling programs, were developed through a collaborative effort of the National Center for Electronics Recycling (NCER), the Product Stewardship Institute (PSI), and the Electronics Recycling

Clearing House (ERCC). Performance measures, to determine best practices for this analysis, were drawn from a rich body of literature, which analyzed similar e-waste policies and programs.

Analytical Framework

The institutional design and analytical framework showing outcomes, was adopted from an assessment conducted by Nives Dolšak (2007). This framework included: identifying the category of actors, the rules for each program, as well as the rules that regulate each e-waste disposal option. The industry specific categories to measure performance, were based on comparative analysis discussed in the previous section. The outcomes were based on program results, convenience for e-waste collection, public awareness and costs of programs (Figure, 1).

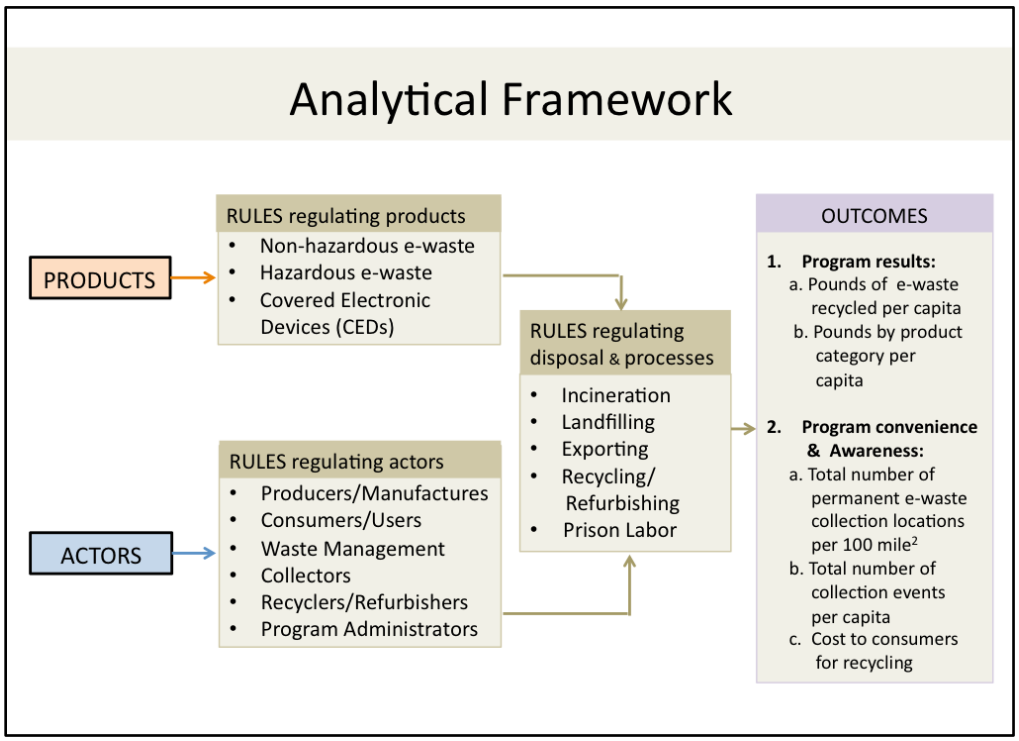

Figure 1:
Analytical Framework and Performance Measures. Outcomes used to analyses and compare the five state e-waste programs. Adapted from Dolsak (2007).

Rules for each state program were recorded to allow a comparison, and to identify potential contributing factors that may influence recycling volumes. Information for the

following categories was collected: covered electronic devices, covered entities (e-g. households, businesses etc…), funding source, incentives, penalties, rules for actors, as well as rules regarding-waste and prison labor, landfills, and incineration.

Program convenience and awareness were based on: the total number of permanent e-waste collection locations per 100 square miles; the total number of collection events; and if there is a cost to consumers to drop off CEDs ERCC, 2013). It is predicted that more collection sites and collection events, will lead to higher levels of convenience for consumers, who will then be more prone to drop off e-waste for recycling (Bhutta, M.K.S., et al, 2011). It was recorded whether or not the consumer is required to pay a fee to drop of e-waste, or if it is free, as this may influence the amount of e-waste recycled, and be a factor in the consumer's participation in the program (Bhutta, M.K.S., et al, 2011). If a the number of collection sites were less than .25/100 square miles it was coded as low; if greater than or equal to .26 and less than .35/100 square miles, it was coded as moderate; and if greater than .36/100 square miles it was coded as high. This range was based on the number of collections sites, divided by 100 square miles and compared to the population in each state[2].

The amount of CEDs collected in pounds per capita in 2012 was calculated for each program. If pounds per capita were less than 3.0 it was coded as low; if greater than or equal to 3.1, and less than 6.0, it was coded as moderate; and if greater than .6.1 it was coded as high. The pounds per capita, number of collection sites, and collection sites per square mile, were used to determine which programs were most successful in 2012. Success is considered being coded as high or high-to-moderate.

The two main categories identified to measure performance of state e-waste policies are: program results, and program convenience and awareness. The NCER, ERCC and PSI

recommended key principles to follow when analyzing and evaluating the success of e-waste programs. Additional performance measures should include the following principles: relevance to industry, quality of data, ease of use, program transparency, accessibility, and adoptability (ERCC, 2010).

There were several data limitations faced with this analysis. First, the three EPR programs, base their fees charged to manufactures, on e-waste that is either sold or recycled in the state. If a CED is sold in one state, and counted as a market share, but is recycled in another state program, and counted as a return share, the manufacturer may pay twice for the same CED. Second, there are no interstate commerce laws to prevent e-waste from moving between states, which makes it difficult to prevent e-waste from going from a state with e-waste landfill laws, into the landfill of a state without e-waste landfill laws. This may lead to recyclers collecting a fee for CEDs, and then sending them to a neighboring state's landfill. Third, manufactures may become unmotivated to surpass, or reach quotas due to "free riders." Finally, because e-waste programs have a variety of covered electronics and covered entities, it is challenging to make equitable comparisons between programs.

Comparative Analysis of Five E-waste Programs in the United States

Calrecycle Program Overview

In 2003, the Electronic Waste Recycling Act (EWRA) was signed into law in California, and amended on September 24, 2004 (SB 50, 2004, Sher). The Calrecycle Program was launched January 1, 2005, and was the first U.S. state to establish an e-waste recycling program. The two main objectives of the EWRA included: limiting the amount of toxic substances in electronic devices sold in California; and establishing a funding mechanism to cover recycling costs for covered electronic devices (CEDs) at end-of-life (Calrecycle, 2013).

California is the only state to implement the Advanced Recovery Fee System (ARF) for electronic products. The program funding comes from a fee charged to consumers at point-of-sale for CEDs. Two state agencies are program administrators, the Public Trust Account (PTA), and the Board of Equalization (BOE), appointed by the California EPA. The role of the PTA is to collect fees from retailers, process requests from registered recyclers and collectors, and provide reimbursement for their services (Calrecycle, 2012).

To be an approved handler of e-waste, collectors and recyclers must notify the Department of Toxic Substance Control (DTSC) and submit an application to the California Integrated Waste Management Board (CIWMB). The DTSC defines e-waste as any electronic device that contains toxic substances. However, all devices that contain toxic substances are not considered CEDs in the Calrecycle program (DTSC, 2013). If an electronic device is not part of the Calrecycle program, but contains toxic material, it is still not allowed to be put in the trash, because California has a ban against hazardous e-waste going into landfills (DTSC, 2013).

Rules Regulating Products

All CEDs must have a permanent label attached, to identify the manufactures brand. Retail stores are only allowed to sell CEDs from manufacturers that are registered annually with the Calrecycle program, and have a brand label attached. As mentioned, consumers are required to pay the fee at time of purchase. If a CED is purchased on-line, or out of state, the law still requires consumers to send the fee to the PTA. Currently, the fee is between $3 and $5 per CED, depending on screen size. The penalty for not paying could be up to $5000 per incident. Covered entities in the program include households and businesses of all sizes. Therefore, large companies could be subject to very large fines if not compliant. See Table 1 for CEDs and other program rules (Calrecycle, 2014b).

Table 1
Calrecycle Program Rules and Relevant Data

Rules for Products, Actors and Disposal Processes	
Covered Electronic Devices (CEDs)	• Computer monitors • Laptop computers • Portable DVD players with liquid crystal display (LCD) screens • Cathode ray tubes (CRTs) and devices that contain CRTs • Televisions (CRTs, LCD and Plasma screens)
Covered Entities	• Households • Businesses of all sizes
Funding Source	Consumers pay fee at point-of-sale for CEDs
Penalties	• Fines up to $5,000 per incident for not paying fees • Recyclers denied full or partial payment for recycling services if documentation is incomplete or inaccurate
Incentives	None
Rules for Processors	• Register annually with Public Trust Account • Keep documentation up dated
Rules for Manufacturers	• Register with Public Trust Account • Maintain documentation and report to program[3].
Rules for Retailers	• Register annually with the Public Trust Account (PTA) • Collect fees from consumers and send to PTA • Educate consumers on how and where to recycle CEDs
Rules for Consumers	Pay fees at point-of-sale, or directly to Public Trust Account
Rules for Waste Management	Not allowed to landfill or incinerate CEDs
Landfill Ban	Yes (CEDs and hazardous e-waste not allowed)
Incineration Ban	No
Prison Labor Ban	Yes

Note. (Calrecycle, 2014a, January)

Rules Regulating Actors

Even though the manufacturers don't appear to play a large role in the program, their obligations take place behind the scenes. As mentioned, one of the main goals of the Calreycle program is to have electronics be less toxic. To remain in the program, all manufactures are required to send a detailed report to the CIWMB. The report requires sales information, a list of retailers, a list showing the amount of hazardous material in the CEDs, and how much recyclable material is in the CED. CIWMB looks for progress by manufacturers to make CEDs less hazardous and easier and safer to disassemble for repair or recycling (Calrecycle, 2012).

Recyclers, refurbishers and collectors must all register annually with the DTSC, as well as submit documentation to the PTA to get reimbursed for recycling CEDs. If documentation is inaccurate or incomplete, the PTA can withhold all, or part, of the recyclers or collectors reimbursement. Processors and collectors are not allowed to charge households or businesses for recycling of CEDs, since they have pre-paid for that service. Non-CEDs may be subject to a fee, but that is up to each business (Calrecycle, 2014b)

Rules Regulating Disposal and Processes

The program administrators of Calrecycle have the authority to suspend or revoke recyclers from participating in the program. The reasons include: improper management of hazardous materials detected by the DTSC during a site inspection; not conforming to DTSC policies; failing to notify Calrecycle of changes to application, or partaking in prohibited activities such as landfilling hazardous e-waste, using prison labor or creating fraudulent reports (Calrecycle, 2012).

In 2006, California implemented a statewide ban against landfilling hazardous e-waste. All consumers including: households, large and small businesses and government agencies are expected to participate in the Calrecycle program. Since the fees are collected up front, and the consumers aren't allowed to dispose of e-waste in landfills, there is an incentive to take end-of-life devices to collectors and processors.

Calrecycle Program Outcomes

The California e-waste program is diligent in reporting the overall volume of CEDs recycled, and pounds per capita, however a detailed list of CEDs by product category was not available (see Table 2). Consistent data was also not found for the number of collection events and permanent sites. There is a current list of collection locations, but the historical information

was not found. The Calrecycle program recycled 65 million pounds of e-waste in 2005, which was 1.8 pounds per capita. In 2012, the amount increased to 214 million pounds, which was 5.7 pounds per capita. The recyclers process a high volume of e-waste. This may be due to the landfill ban, the threat of large fines for doing the wrong thing with e-waste, or because of the 515 collection locations around the state (Calrecycle, 2013).

Table 2
Calrecycle's Program Outcomes

Program Results								
	2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
CEDs recycled (pounds)	65 M	128 M	185 M	218 M	186 M	194 M	198 M	214 M
CEDs recycled/capita (pounds)	1.8	3.5	5.0	5.8	5.0	5.4	5.5	5.7
CEDs By Product Category and Covered Entity Type:								
CEDs by product category (pounds)	Not Reported	Not Reported	Not Reported	Not Reported	Not Reported	Not Reported	Not Reported	Not Reported
Convenience and Awareness								
Number of collection sites	Not Reported	Not Reported	Not Reported	Not Reported	Not Reported	Not Reported	Not Reported	515
Number of collection events	39	55	88	Not Found	Not Found	Not Found	Not Found	Not Found
Cost paid by consumer at P.O.S.*	Not Available	Not Available	Not Available	Not Available	Not Available	$8-$15	$6-$10	$6-$10

Note. Data retrieved from Calrecycle (2013).

Considering the Calrecycle Program was established in 2005, the available data was limited. Having access to more detailed data would be helpful to identify how long consumers keep CEDs before recycling devices, as well as other patterns.

E-Cycle Washington Program Overview

The Governor of Washington signed the e-waste law on March 24, 2006. On October 2007, the Washington Department of Ecology (DOE) adopted the Electronic Products Recycling

Program – "WAC 173-900" E-Cycle Washington. The program policies are based on an Extended Producer Responsibility (EPR) model, and the Return Share principle. The Return Share is based on how many pounds of CEDs are returned for recycling, then an estimated percent is attributed to manufacturers, based on the amount of CEDs sold in previous three years. The manufacturers must also pay a percentage of "orphan" CEDs. Orphans are electronic devices where the manufacturer (brand owner) is no longer in business or could not be identified (ECY, 2014).

The covered entities who can participate in the recycling program include: households, small businesses (less than 50 employees), local governments and charities. These entities can drop off CEDs (see Table 3) at no cost to collectors and processors, registered in the program. Non-covered electronic devices may require a fee (E-Cycle Washington, 2013).

Table 3
E-Cycle Washington Program Rules and Relevant Data

Rules for Products, Actors and Disposal Processes	
Covered Electronic Devices	• Computer monitors • Laptop computers • Cathode ray tubes (CRTs) and devices that contain CRTs • Televisions (CRTs, LCD and Plasma screens) • Notebooks and e-readers
Covered Entities	• Households • Small businesses (less than 50 employees) • Local governments • Charities
Funding Source	Manufacturers pay annual fee based on return share of CEDs sold
Penalties	• Manufactures fined up to $10,000 for not meeting recycling quotas • Manufacturers/ retailers fined up to $2,000 for inproper labeling CEDs
Incentives	Avoid Penalties
Rules for Processors	Register annually with DOE and maintain required documentation
Rules for Manufacturers	Register with DOE and pay annual fees
Rules for Retailers	• Only CEDs from registered manufacturers • Only sell CEDs that are properly labeled with brand • Educate consumers about e-Cycle program and recycling
Rules for Consumers	• Do not throw electronics in trash • Take e-waste to program collector or processor
Rules for Waste Management	Make best efforts to divert CEDs to collectors in E-Cycle
Landfill Ban	No (Some counties have bans on hazardous e-waste)
Incineration Ban	No
Prison Labor Ban	Yes (Not allowed)

Note. Data retrieved from E-Cycle WA (ECY, 2014)

Rules Regulating Products

CEDs that are not part of the E-Cycle Washington program may or may not contain hazardous waste. However, all electronics contain finite resources that need to be retrieved versus lost to a landfill. Almost all electronics contain flame retardants, which are carcinogenic when burned, which is often done in open air pits in Africa and China (The Wasteland, 2008), or even in the U.S, which was the case at Stone Castle Recycling in Utah (BAN, 2014). Washington doesn't currently have a statewide ban on putting non-CEDs in landfills, but recycling should be considered strongly as the option (ERCC, 2013).

Rules Regulating Actors

Rules for the manufacturers require they register with Washington's Department of Ecology (DOE), and pay an annual fee based on a return share system. Companies pay between $7 and $37,217 annually depending on how many CEDs of their brand are purchased in Washington. The fees cover future recycling of the CEDs. The manufacturers must also ensure CEDs are recycled by promoting collection events and collector programs, which are referred to as collection sites. If recycling quotas for the manufacturers are not met, the DOE can administer a fine up to $10,000. The fines are incentives to ensure companies actively promote consumers to recycle electronics, especially the CEDs (Till, 2007).

Rules for recyclers, refurbishers and collectors require submitting documentation and reports to the DOE annually. These reports include itemized list of CEDs by volume to help determine the return share. These reports are combined with reports from the retail stores, and the DOE calculates each manufacturers return share percent, and sends a fine to companies that didn't meet the quota (E-Cycle WA, 2007).

There are no specific rules for consumers, but they are expected to do their part by taking end-of-life electronics to a program collector or processor. Manufacturers complain because they can't force people to recycle CEDs, or prevent them from putting CEDs in a landfill (Till, 2007). Since there are no statewide landfill bans in Washington, there may be less motivation to recycle compared to states with landfill bans.

Rules Regulating Disposal and Processes

As mentioned, putting e-waste in landfills in Washington is not prohibited, nor is incineration or prison labor. This study was not able to determine if collectors or recyclers, not in the E-Cycle WA program, use these methods of disposal. It would be a good test if a landfill bam is implemented, to see if it would cause a spike in the volume of e-waste recycled.

E-Cycle Washington's Program Outcomes

Since the program started, there has been a 17% increase in the amount of CEDs collected for recycling (Table 4). The pounds per capita collected went from 5.8 pounds in 2009 to 7.3 in 2013. The CEDs are reported by category, with the following percentage distribution of devices recycled in 2012: televisions were 74 percent of CEDs recycled, monitors were 18 percent, and computers were 8 percent. Based on findings from Milovantseva and Saphones (2013), consumers may be more likely to recycle their CEDs, such as televisions that don't contain memory and private information, (e.g social security numbers and bank information,). Also, devices with personal data are more likely to get stored versus recycled. Manufacturers in the program conducted 83 collection events in 2012, and there were 332 permanent collection sites (.48/mile^2).

Table 4
E-Cycle Washington's Program Outcomes

Program Results					
	2009	**2010**	**2011**	**2012**	**2013**

CEDs recycled (Pounds)	**38,509,563**	**39,467,798**	**42,140,190**	**43,473,038**	**45,180,945**
CEDs recycled/ Capita (Pounds)	**5.8**	**6.3**	**6.9**	**7.1 (High)**	**7.3**
CEDs By Product Category and Covered Entity Type:					
Televisions					
Household	22,157,784	24,873,291	29,076,120	31,946,368	35,423,879
School Dist.	64,740	47,769	46,365	6,080	48,8914
Sm. Biz	128,088	48,579	134,856	158,442	114,102
Total TVs	**22,350,612**	**24,969,639**	**29,257,341**	**32,110,890 (74%)**	**35,586,872**
Monitors					
Household	11,537,361	10,390,936	9,107,361	7,654,175	6,077,277
School Dist.	619,220	309,762	164,046	181,171	230,549
Sm. Biz	105,375	24,428	52,935	47,676	40,614
Sm. Govt.	25,778	13,114	2,967	7,737	1,605
Total Monitors	**12,287,734**	**10,7382240**	**9,327,309**	**7,890,759 (18%)**	**6,350,045**
Computers					
Household	3,593,279	3,637,878	3,460,140	3,313,137	3,053,933
School Dist.	296,463	115,514	113,169	138,271	156,602
Sm. Biz	15,899	4,232	28,872	18,2666	26,672
Sm. Govt.	4,687	2,295	6,207	2,415	6,821
Total Computers	**3,910,328**	**3,759,919**	**3,608,388**	**3,472,089 (8%)**	**3,244,028**
TOTAL					
Convenience and Awareness					
Number of collection sites per capita	Not Found	Not Found	Not Found	0.48 (High)	Not Available
Number of collection events	Not Found	Not Found	Not Found	83	Not Available
Costs paid by consumer to drop off CEDs	NO	No	No	No	No

Note. Data retrieved from E-Cycle Washington,(2013) and the DOE (ECY ,2014)

E-Cycle Wisconsin Program Overview

The Wisconsin e-waste bill was signed into law on October 23, 2009 (s.287.17, Wis Stats.), and the e-Cycle Wisconsin Program started on January 1, 2010. The program follows a market share model. The market share is based on the manufacturers actual share of the market versus an estimate. This is based on the amount of CEDs sold at registered retail stores in previous years. This program type is an example of one that could cause a manufacturer to pay

for CEDs to get recycled more than one time, if the devices are taken to another state after being purchased in Wisconsin.

The state policy includes a ban on putting e-waste in landfills. The main goals of the program have been to keep CEDs out of landfills, improve recycling convenience for consumers, place the burden of recycling costs on the producers, decrease administrative costs for the state agencies, and increase recycling jobs (WI-DNR, 2013).

Rules Regulating Products

The consumer's CEDs are collected for free for recycling by processors and collectors registered with the program. The consumers include: households and K-12 schools. Businesses and governmental agencies are not included in the program and must pay for recycling of electronic devices (see Table 5).

Table 5
E-Cycle Wisconsin Program Rules and Relevant Data

Rules for Products, Actors and Disposal Processes	
Covered Electronic Devices	• Computer monitors • Laptop computers • Portable DVD players with liquid crystal display (LCD) screens • Cathode ray tubes (CRTs) and devices that contain CRTs • Televisions (C RTs, LCD and Plasma screens) • Printers • Fax machines • Keyboards
Covered Entities	• Households • K – 12 Schools
Funding Source	• Manufactures annual registration fees • Return Share fees
Penalties	**Manufacturers:** • Failure to meet annual quotas: pay fee based on amount of e-waste short-fall in pounds (based on current per pound weight) + 10% **Consumers:** • Fine of $500 per CED that is not recycled properly **Processors:** • Failure to be compliant to program policies may include fines and/or removal from program
Incentives	**Avoid penalties**
Rules for Processors	• Must use either e-Stewards or R2 recyclers in program (6) • No state or federal prison labor allowed

Rules for Manufacturers	• Register annually with program administration • Pay annual fees • Maintain documentation • Attach brand labels on all CEDs
Rules for Retailers	• Only sell CEDs of manufacturers registered in program • Ensure brand labels are on CEDs • Educate consumers about recycling CEDs at end-of-life
Rules for Consumers	• Recycle all CEDs with processors in program • Do not put e-waste in trash
Rules for Waste Management	• Do not put CEDs in landfill
Landfill Ban	Yes (Hazardous e-waste not allowed)
Incinerator Ban	No
Prison Labor Ban	Yes (Not allowed)

Note. Data received from E-Cycle Wisconsin Program (WI-DNR,2013).

Rules Regulating Actors

The manufacturers pay for the cost of recycling based on a Market Share model. Market Share is based on the amount of CEDs sold to households and schools in the state, in the previous three years. The fee rate is: less than 25 CEDs sold = no fee; 25 to 249 CEDs sold = $1,250 fee; and greater than 250 CEDs sold = $5,000 fee (WI-DNR, 2013).

Manufactures are also required to meet an annual recycling quota, and ensure 80 percent of the CEDs sold (measured by volume, not unit) are recycled by processors registered in the E-Cycle Wisconsin program. If a company fails to meet the 80 percent quota there is a "shortfall fee" required. The fee is between $0.30 and $0.50 per pound, depending on the size of shortfall. Companies can accrue up to 20 percent credits for future years if they exceed their quota. Companies are allowed to use credits or sell credits to another company (WI-DNR, 2013). This incentive is to encourage companies to continue the promotion of recycling, after meeting their annual quota.

Recyclers, refurbishers and collectors are required to register with the DNR annually and submit documentation to get reimbursed for processing CEDs. Retail stores are required to register with the DNR, and only sell brands of CEDs of registered manufactures. Retailers are

also required to educate consumers regarding the landfill and incineration bans, as well as where and how to recycle CEDs at the products end-of-life.

Wisconsin is one of the 19 states with a ban against putting e-waste in landfills; therefore it is illegal for consumers to throw old electronics in the trash. Consumers are often required to pay collectors when CEDs are dropped off. The cost ranges from $5 to $40, depending on the size of the device. Some collectors charge 15 to 25 cents per pound versus a flat fee (WI –DNR, 2013).

Rules Regulating Disposal and Processes

Wisconsin has a ban against putting hazardous e-waste in landfills, but there is not an incineration ban.

E-Cycle Wisconsin's Program Outcomes

Based on 2012, the E-Cycle Wisconsin program recycled 6.73 pounds per capita, which is considered a moderate amount. There were 53 collection events, and .80 permanent collection sites per 100 square miles. One of the main goals of the recycling program administrator is to keep e-waste out of landfill, which is an performance indicator that the program is successful. (See Table 6 for program outcomes).

Table 6
E-Cycle Wisconsin Program Outcomes

	Program Results			
	2010	**2011**	**2012**	**2013**
CEDs recycled (pounds)	24,168,103 M	35,149,909 M	39,098,317 M	38,755,751 M
CEDs recycled per capita (pounds)	4.2	6.12	6.83	6.77
CEDs By Product Category:				
Televisions	55% (13,292,457 M)	64%	64% (25,022,923 M)	62%
Monitors	18%	20%	10%	11%
Computers	9%	6%	7%	8%

Other CEDs	16%	10%	20%	20%
Convenience and Awareness				
Number of collection sites	305 .50/100 mile^2	340 .60/100 mile^2	450 .80/100 mile^2	700 1.2/100 mile^2
Number of collection events	Not Reported	Not Reported	53	Not Reported
Costs paid by consumer to drop off CEDs	No	No	No	No

Note. Data retrieved from E-Cycle Wisconsin (WI DNR, 2013).

E-Cycle Oregon Program Overview

The e-waste bill was signed on June 7, 2007 and the e-Cycle Oregon program started on January 1, 2009. The program is based on the Extended Producer responsibility (EPR) framework, and is a combination of Return Share and Market Share models. There are currently four programs that make-up e-Cycle Oregon. These programs include: The Oregon Department of Environmental Quality (DEQ), the National Center for Electronics Recycling (NCER); the Manufacturing Recycling Management Company, LLC and the Manufacturers Group Plan, which is managed by the Reverse Logistics Group Americas, Inc. Manufacturers have the option to join an existing state contractor plan, or start their own program. The programs are required to register manufacturers and CEDs, approve manufacturer's programs, calculate return share and annual registration fees, and hold program contractors accountable (Oregon DEQ, 2014).

Rules Regulating Products

Collectors and recyclers are required to accept CEDs at no charge. A unique aspect of this program is only households and small business (49 employees or less) are covered entities. However, anyone can drop of up to 7 items that are CEDs, at no charge.

Rules Regulating Actors

Programs are fully funded by the manufactures, and are based on return shares of CEDs, with the exception of television, which are based on market share. To determine return share, a manufacturer's total weight of sold CEDs with their brand label, is divided by the total weight of CEDs sold in a given time period. All manufactures are required to pay for orphans (CED brand that is no longer in business). CEDs are based on a percent of their return share. Manufactures that produce more televisions compared to other CEDs, pay fees based on the market share, which is based on how many televisions were sold three years previously (Oregon DEQ, 2014).

The manufacturers are required to provide free recycling for CEDs, as well as convenient state-wide collection locations. Convenience translates to, a minimum of one collection site in cities with a population of 10,000 or greater. Each county must also have retailer take-back programs and occasional collection events. Manufacturers are also required to educate, advertise and promote collection opportunities statewide (Oregon DEQ, 2014). (see Table 7 for rules)

Rules Regulating Disposal and Processes

There is a state-wide ban against putting hazardous e-waste in landfills in Oregon.

Table 7
E-Cycle Oregon Program Rules and Relevant Data

Rules for Products, Actors and Disposal Processes	
Covered Electronic Devices	• Computer monitors • Laptop computers • Portable DVD players with LCD screens • Cathode ray tubes (CRTs) and devices that contain CRTs • Televisions (CRTs, LCD and Plasma screens) • Printers • Fax machines • Keyboards
Covered Entities	• Households • K – 12 Schools
Funding Source	• Annual registration fees paid by manufacturers
Penalties	• Manufactures to pay fine for shortfall of quota at going rate per pound to recycle e-waste, plus an additional 10% • Consumers fined $500 per incident if CEDs are put in trash
Incentives	
Rules for Processors	• Register annually with program administrator

	• Maintain accurate documentation • Collect CEDs with no charge to covered entities
Rules for Manufacturers	• Register annually with program administrator • Maintain accurate documentation • Pay annual fees based on return and market share • Brand labels must be on all CEDs
Rules for Retailers	• Only sell CEDs of manufacturers registered in program • Ensure brand labels are on CEDs • Educate customers about recycling CEDs through program
Rules for Consumers	• Recycle all CEDs with processors in processors in program • Do not throw CEDs in trash
Rules for Waste Management	• Do not put CEDs in landfill
Landfill Ban	Yes
Incinerator Ban	No
Prison Labor Ban	No (Allowed)

Note. Data retrieved from (Oregon DEQ, 2013-2014)

E-Cycle Oregon Program Outcomes

In 2012, the E-Cycle Oregon program recycled 6.84 pounds of CEDs per capita, which is considered moderate/high. There were 8 collection events reported and 0.29 collection sites per 100 square miles, which is coded at the moderate level. There is a statewide landfill ban against hazardous e-waste going into solid waste landfills. Manufacturers have quotas and penalties. The penalties require paying the difference in cost per pound, of the missed quota, plus an additional 10%. (see Table 8 for additional program outcomes).

Table 8
E-Cycle Oregon Program Outcomes

Program Results					
	2009	**2010**	**2011**	**2012**	**2013**
CEDs recycled (pounds)	19.0 M	24.2 M	25.9 M	26.7 M	27.7 M
CEDs recycled per capita (pounds)	4.96	6.3	6.75	6.9	7.1
CEDs By Product Category:					
Computers/ Notebooks	798,868	1,275,662 15%	553,409 15%	881,820 13%	921,439 11%
Monitors	2,028,180	2,400,828 28%	878,697 23%	1,327,217 19%	1,166,041 14%
Televisions	2,792,754	4,803,290 57%	2,332,837 62%	4,623,072 68%	6,333,637 75%
Total	**5,619,802**	**8,479,780**	**3,764,943**	**6,832,109**	**8,421,117**
Convenience and Awareness					

Number of collection sites	220	240	230	282	301
Number of collection events	22	17	13	8	18
Costs paid by consumer to drop off CEDs	Not for CEDs	Not for CEDs	Not for CEDs	Not for CEDs	Not for CEDs

Note. Net pounds collected by Oregon SCP 2009-2013. The data is from Oregon E-Cycles Biennial Report (Oregon E-Cycle, 2013).

Utah Program Overview

The Utah e-waste recycling bill was signed into law by Governor Gary Herbert, and it came into effect July 1, 2011. The policy requires manufactures to report all CEDs being sold in the state, to Utah's Department of Environmental Quality (Utah DEQ). The manufacturers are also required to provide a public education program, about recycling electronic devices, and develop educational materials that inform consumers about recycling programs. The law allows local government to work with manufacturers to facilitate consumer electronic recycling (ERCC, 2013).

The Utah DEQ is required to forward the manufacturers reports to the following agencies or committees: Natural Resource, Agriculture, Public Utilities, Environment Interim and Technology Committees (Utah DEQ, 2013). Of the programs analyzed, Utah has the most limited requirements of all actors involved. The main focus is on manufacturers providing education to consumers, and documentation about CEDs sold in the state. Accountability or requirements for other actors is not established at this time (Utah DEQ).

Rules Regulating Products

There are no rules regulating products. However, there is a list of electronics that are recommended for recycling at end-of-life.

Rules Regulating Actors

Manufacturers are required to fund the education programs. There was no money appropriated in the bill, and at this time, there is no program in place that registers processors, collectors, or transporters in Utah. There is a list of e-waste recyclers, and a list of questions to ask potential recyclers on Utah's DEQ website.

Rules Regulating Disposal and Processes

There are no landfill bans (see Table 9).

Table 9
Utah Department of Environmental Quality Program Rules and Relevant Data

Utah DEQ Program	**Overview of Relevant Data**
Covered Electronic Devices	• Computer monitors • Laptop computers • Notebooks and Tablets • Portable DVD players with LCD screens • Cathode ray tubes (CRTs) and devices that contain CRTs • Televisions (CRTs, LCD and plasma screens) • Printers • Keyboards
Covered Entities	• None
Funding Source	• Manufacturers to provide and pay for consumer education regarding e-waste
Penalties	• None specified
Rules for Processors	• None specified
Rules for Manufacturers	• Provide education about proper e-waste recycling to consumers • Send documentation regarding CEDs to Utah's DEQ
Rules for Retailers	• None specified
Rules for Consumers	• None specified
Rules for Waste Management	• None specified
Landfill Ban	No
Incineration Ban	No
Prison Labor Ban	No (Allowed)

Note. Data retrieved from Utah-DEQ (2013).

Utah's Program Outcomes

The only outcome available regarding Utah's recycling program was from 2012. The amount of e-waste recycled, was 2.98 pounds per capita, which is low. There were no collection events reported or collection sites. There are 32 recyclers listed on Utah's Department of Environment. One of the recycles on the list is Stone Castle Recycling that stockpiled over 300 containers (4 X

4 cubic feet) of e-waste, which then caught on fire in March, 2014 (BAN, 2014). (see Table 10 for program results).

Table 10
Utah Department of Environmental Quality Program Outcomes

Program Results			
	2011	**2012**	**2013**
CEDs recycled (pounds)	Not Reported	**8,500,000**	Not Reported
CEDs recycled per capita (pounds)	Not Reported	**2.98 (low)**	Not Reported
CEDs by Product Category	Not Reported	Not Reported	Not Reported
Convenience and Awareness			
Number of collection sites	Not Reported	Not Reported	Not Reported
Number of collection events	Not Reported	Not Reported	Not Reported
Costs paid by consumers to drop off CEDs	**Yes**	**Yes**	**Yes**

Note. Key results for Utah program are in box under 2012 (ERCC, 2014). .

Results

The five programs analyzed were established in different years ranging from 2005 to 2011. The data compared for this analysis was based on 2012, because it was the first full year there was data available for all five states (see Table 11). Washington State showed the highest success rate based on the amount of e-waste recycled in 2012, with 7.1 pounds per capita recycled, and 0.48 collection sites per 100 square miles, and 83 collection events. Wisconsin, has the highest number of collection sites, with .80 sites per 100 square miles, and had 53 collection events, and collected 6.73 pounds per capita of e-waste, which is coded as a moderate to high outcome. Oregon had 0.29 collection sites per 100 square miles and collected 6.84 pounds per capita of e-waste for recycling, which is coded as a moderate to high outcome. California is in

the moderate range for all outcomes, and Utah was the least successful with only 2.98 pounds per capita of e-waste recycled.

Table 11
Outcomes and findings of comparison analysis of e-waste programs.

Findings

Program Name & State	RULE: Manufacturers Incentive to take back electronics?	RULE: Are CED's collected for free?	RULE D & P: Landfill and /or Incinerator Bans ?	E-waste recycled (Pounds per Capita)	Collection Events	Collection Sites (per 100 Miles²)
Cal Recycle	No	Yes • Households • Businesses	LF: Y In: N	5.65 (Mod.)	Not Reported	0.32 (Mod.)
E-Cycle Oregon	< Quota = Penalty fee	Yes • Households • Small businesses • Anyone ≤7 items	LF: Y In: N	6.84 (Mod.)	8	0.29 (Mod.)
Utah DEQ	No	No	LF: N In: N	2.98 (Low)	Not Reported	Not Reported
E-Cycle Washington	< Quota = Penalty fee	Yes • Households • Small businesses	LF: N In: N	7.1 (High)	83	0 .48 (High)
E-Cycle Wisconsin	Yes Shortfall fees	Yes • Households • Schools (K-12)	LF: Y In: N	6.73 (Mod.)	53	0.80 (High)

KEY:
Lbs./capita:
Low = < 3.0;
Moderate = ≥3.1 < 6.0;
High = > 6.1

Collection Sites/100 Sq. mile:
Low = < .25
Moderate = > .26 < .35;
High = > .36

Washington also had the most permanent collection locations per square mile, which suggests convenience may be a motivating factor for consumers to recycle their e-waste. All state programs analyzed, except for Utah, included "households" as covered entities who are allowed to participate in programs, and drop off CEDs for free. Only California and Utah have no quotas for manufacturers to meet, regarding the amount of CEDs that are recycled. This suggests quotas and penalties may be a contributing factor to why Washington had the highest

amount of CEDs recycled, and Oregon (6.84 pounds per capita) and Wisconsin (6.73 pounds per capita) were in second and third place for amount of CEDs recycled.

Conclusions

The outcomes of this analysis suggest that a higher number of collection sites per 100 square miles, correlates with a higher amount of e-waste recycled per capita, which suggests convenience is a contributing factor for consumers to recycle their e-waste. The outcomes also suggest, programs with a higher number of CEDs collected for free, also had a higher amount of e-waste recycled, which suggest that cost is a factor for consumers.

In states, where there are monetary penalties for manufacturers, when they don't meet quotas, there was a higher amount of e-waste recycled per capita. Positive incentives didn't appear to influence program success. For example, Wisconsin has an incentive if the quota is met, they get up to 20% surplus recycling volume, which can rollover to the next year, or can be sold to another manufacturer (ETBC, 2013). Washington and Oregon don't have that incentive, and they both had higher volumes of e-waste recycled per capita. However, Washington and Oregon do have penalties if they don't reach their quotas. A contributing factor to this difference may be the "free rider" issues suggested by Hickle (2013), and Atasu and Subramanian (2011). Since the sample size is small, additional analysis of other programs will be needed.

Furthermore, based on this analysis, it was not conclusive if landfill bans impact the amount of e-waste recycled. Washington had the highest amount of e-waste recycled per capita, and there is no landfill ban. California, Oregon and Wisconsin have bans against putting e-waste in landfills, but they all scored moderate.

Future Study

Plans for future study include, applying this analytical structure, performance measures and outcomes to more states with policies and programs. This will allow a larger sample and increase confidence in the results. It would be beneficial in future work to conduct surveys with recycling program administrators to gather more in depth details and program data, which is not posted on websites. It would also be beneficial to conduct consumer surveys to identify the level of program awareness. Another valuable category would be to compare the number of jobs, in relation to the amount of e-waste recycled. It is obvious that there are multiple contributing factors to the performance of e-cycle programs. Further investigation and evaluations will be beneficial for current and potentially new state recycling programs.

About the Author

Mandy Knudtson is a graduate student at the University of Washington, Bothell, and is a candidate for a Master of Arts and Policy Studies (MAPS). Mandy's focus is environmental policy, specifically state, federal and international policies regarding electronic waste. Mandy works in Seattle, WA at the Basel Action Network (BAN), an international, non-profit organization, focused on the prevention of hazardous e-waste from being exported to developing countries. Mandy is the e-Stewards Business Director of the international e-waste certification program known as the e-Stewards Standard.

References

Adrian, S. (2013, May 13). Cleaning up electronic waste (e-waste). U.S. Environmental Protection Agency (EPA). Retrieved on September 13, 2013, from http://www.epa.gov/international/toxics/ewaste/

Atasu, A. and Subramanian, R. (2012, November/December). Extended producer responsibility For e-waste: individual or collective producer responsibility? Production and Operations Management. 21 (6) 1042-1059. Retrieved from http://web.b.ebscohost.com.offcampus.lib.washington.edu/ehost/pdfviewer/pdfviewer?vid=3&sid=84c613e0-36d7-4475-aa8f-e7f9896d7a90%40sessionmgr111&hid=114

BAN. (2014, March 19). Electronic waste nightmare in Utah revealed. Retrieved April 30, 2014, from http://www.ban.org/files/reports/Stone_Castle_Recycling_LLC_Comp.pdf

Basel Convention. (2013). www.basel.int. Retrieved December 30, 2013, from http://www.basel.int/TheConvention/Overview/TextoftheConvention/tabid/1275/Default.aspx

Bhutta, M.K.S., Omar, A., and Yang, X. (2011, April5). Electronic waste: A growing concern in today's environment.Economic Research International. Hindawi Publishing Corporation. 2011 (474230) 1-8. Retrieved from http://www.hindawi.com/journals/ecri/2011/474230/

Calrecycle (2012, June). Update on California's covered electronic waste recycling program. Retrieved on October 30, 2013 from http://www.calrecycle.ca.gov/electronics/CEW/ProgramStats.pdf

Calrecycle. (2013). Electronic Waste Recycling Act of 2003: Covered Electronic Waste Payment System (SB 20/SB 50) Electronic Product Management. www.calrecycler.ca.gov. Retrieved on January 27, 2014, from http://www.calrecycle.ca.gov/Electronics/Act2003/

Calrecycle. (2014a). Ca.gov. http://www.calrecycle.ca.gov/default.asp

Calrecycle. (2014b, January 10). Calrecycle 2012 Enforcement Report. (p. 34-36). Retrieved on January 13, 2014, from http://www.calrecycle.ca.gov/Publications/Documents/1485/20141485.pdf

CDC. (2013). Center for Disease Control. www.cdc.gov.

Dolšak, N. (2007). An assessment of tradable permits for common-pool resources. *Review of Policy Research*, 24 (6): 541-565.

DTSC. (2014). Department of Toxic Substance Control, California. http://www.dtsc.ca.gov/

Ecy. (2014). Department of Ecology State of Washington. http://www.ecy.wa.gov/

E-Cycle Washington. (2007, November). Environmentally sound management and performance standards for direct processors: Washington State electronic product recycling program. Department of Ecology State of Washington. Retrieved from http://www.ecy.wa.gov/programs/swfa/eproductrecycle/docs/PreferredPerformanceStdsFinal2007.pdf

E-Cycle Wisconsin (2011, April). E-Cycle Wisconsin 2010 report. Retrieved on January 3, 2014 from http://dnr.wi.gov/files/PDF/pubs/wa/WA1529.pdf

E-Cycle Wisconsin (2011, December) E-Cycle Wisconsin program year 2 results. Retrieved on January 3, 2014 from http://dnr.wi.gov/files/PDF/pubs/wa/WA1559.pdf

E-Cycle Washington (2013). E-Cycle Washington Standard Plan 2009-2013 Annual Reports – workbook format. Retrieved on January 3, 2014, from http://www.ecy.wa.gov/programs/swfa/eproductrecycle/

ERCC. Electronic Recycling Coordination Clearinghouse. (2010, September) ERCC Best practices for measuring the performance of state electronics recycling programs. Retrieved on November 11, 2013 from http://www.ecycleclearinghouse.org/documents/ERCC%20Best%20Practices%20for%20Performance%20Measures%20FINAL.pdf

ERCC. Electronics Recycling Coordination Clearinghouse. (2013). States with landfill bans. Retrieved on January 13, 2014 from http://www.ecycleclearinghouse.org/Content.aspx?pageid=58

ERCC. (2014). Latest per capita data on electronic recycling programs. Retrieved on January 27, 2014, from http://www.ecycleclearinghouse.org/Content.aspx?pageid=59

ETBC. (2009, November 13). Comparison of state e-waste laws. Electronics Take Back Coalition Retrieved on December 3, 2013, from http://www.electronicstakeback.com/wp-content/uploads/Detailed%20State%20Law%20Comparison%20ALL

ETBC. (2011, September 27). States where you can't throw away e-waste into the trash. Electronic TakeBack Coalition Retrieved on November 17, 2013 from http://www.electronicstakeback.com/wp-content/uploads/Disposal_Ban_Bills.pdf

ETBC. (2013a, August 19) How much e-waste is collected in states with electronics recycling laws? Electronics Take Back Coalition. Retrieved on September 27, 2013 from http://www.electronicstakeback.com/wp-content/uploads/Collection_Volumes_by_State.pdf

ETBC.(2013b, September 25). Facts and figures on e-waste and recycling. Electronics Take

Back Collision Retrieved on December 22, 2013from http://www.electronicstakeback.com/wp-content/uploads/Facts_and_Figures_on_EWaste_and_Recycling.pdf

Gallo, D.T. (2013, July 15). Broad view of e-waste management policies in the U.S. Global E-Waste Management (GEM) Network Workshop. U.S. Environmental Protection Agency. (EPA) Retrieved on September 17, 2013 from http://www.epa.gov/international/regions/Asia/taiwan/iemn-pdfs/overview.pdf

Greenemeir, L. (2009, October 29). U.S. lags behind world with its patchwork approach to curbing e-waste. Scientific American. Retrieved on January 27, 2014, from http://www.scientificamerican.com/article/electronic-waste-control/

Hickle, G.T. (2013, March 19). Comparative analysis of extended producer responsibility policy in the United States and Canada. *Journal of Industrial Ecology*. *17* (2) 249-261. Retrieved on September 27, 2013 from http://onlinelibrary.wiley.com.offcampus.lib.washington.edu/doi/10.1111/jiec.12020/full

Kiddee, P., Naidu, R., Wong, M.H. (2013, May). Electronic waste management approaches: An overview. Waste Management. *33* (5) 1237-1250. Retrieved on September 27, 2013 from http://www.sciencedirect.com.offcampus.lib.washington.edu/science/article/pii/S0956053X13000147

Mayers, K. and Butler, S. (2013, March) Producer responsibility organizations development and opperations. *Journal of Industrial Ecology*. *17* (2) 277-289. Retrieved on September 17, 2013 from http://onlinelibrary.wiley.com.offcampus.lib.washington.edu/doi/10.1111/jiec.12021/pdf

Meigs, D. (2012, October, 5). Smartphones, foolish waste. China Daily. Retrieved on January 27, 2014, from http://www.chinadaily.com.cn/hkedition/2012-10/05/content_15797059.htm.

Milovantseva, N., Saphones, J.D. (2013, July 30). E-waste bans and U.S. households' preferences for disposing of their e-waste. *Journal of Environmental Management*. *124* 8-16. Retrieved on September 17, 2013 from http://www.sciencedirect.com.offcampus.lib.washington.edu/science/article/pii/S0301479713001722

Milovantseva, N., Saphones, J.D. (2013, March). Time bomb or hidden treasure? Characteristics of junk TVs and of the US households who store them. *Waste Management*. *33* (3) 519-529. Retrieved on September 17, 2013 from http://www.sciencedirect.com.offcampus.lib.washington.edu/science/article/pii/S0956053X12003200

Nash, J. and Bosso, C. (2013, April) Extended producer responsibility in the United States: Full speed ahead? *Journal of Industrial Ecology*. 17 (2) 175-185. Retrieved on September 27, 2013 from

http://onlinelibrary.wiley.com.offcampus.lib.washington.edu/doi/10.1111/j.1530-9290.2012.00572.x/abstract

NCER. National Center for Electronics Recycling. (2010). http://www.electronicsrecycling.org/public/

NCMS. (2013). Electronic waste state resource locator. National Center for Manufacturing Sciences. www.ncms.org. Retrieved from http://www.envcap.org/statetools/ewaste/

Oregon E-Cycles (2009-2013). Net pounds collected by Oregon SCP. (5 Reports) www.ElectronicRecyclking.org Retrieved on February 1, 2014, from http://www.electronicsrecycling.org/oregon/public/contentpage.aspx?pageid=4

Oregon DEQ. (2012, January, 28). Recap to Support Additional Comment on Fee Rule Concepts Retrieved on January 4, 2014 from http://www.deq.state.or.us/lq/ecycle/pubs/ECyclesRMAdvCommRecap120128.pdf

Oregon DEQ. (2014, January). Oregon e-cycles biennial report. State of Oregon Department of Environmental Quality. Retrieved from http://www.deq.state.or.us/lq/pubs/docs/ORECyclesBiennialReportLeg2014.pdf

Puckett, J. (2013, June 17). The five fatal flaws: A concise critique of the R2:2013 Standard. Basel Action Network. Retrieved on March 15, 2014 from http://ban.org/Library/FiveFundamentalFlawFinal.pdf

Rainforest Relief. (2014). Retrieved on February 28, 2014from http://www.rainforestrelief.org/What_to_Avoid_and_Alternatives/Aluminum.html

Seltenrich, N. (2013, August, 28). Incineration versus recycling: in Europe, a debate over trash. E360 Environment. Retrieved on February 17, 2014 from http://e360.yale.edu/feature/incineration_versus_recycling__in_europe_a_debateoover_trash/2686/

The Wasteland. (2008, November). " CBS, 60 Minutes. Prod. Solly Granatstein. Host Scott Pelley. CBS Television. 9 Nov. 2008. Web. 28 Feb. 2012.

Till, D. (2007, November 7). Washington State electronics waste recycling rules go into effect. Retrieved on February 2, 2014, from http://www.martenlaw.com/newsletter/20071107-wash-e-waste-rules.

U.S. EPA. (2011, July 20). National strategy for electronics stewardship. Retrieved on September 2, 2013 from http://www.epa.gov/wastes/conserve/materials/ecycling/taskforce/docs/strategy.pdf

U.S.EPA.(2013, September 9). Environmental Protection Agency. FAQ: Regulations for used

Cathode Ray Tubes CRTs and CRT glass. Retrieved on January 13, 2014 from http://www.epa.gov/epawaste/hazard/recycling/electron/crt-faq.htm

U.S. EPA (2014a). http://www.epa.gov/

U.S.EPA. Environmental Protection Agency (2014b). Managing electronic wastes and e-cycling. Retrieved on January 13, 2014 from http://www.epa.gov/region4/rcra/ecycling.htm

U.S.EPA. Environmental Protection Agency. (2014c, February). Municipal solid waste generation, recycling, and disposal in the United States. Retrieved on January 15, 2014 from http://www.epa.gov/wastes/nonhaz/municipal/pubs/2012_msw_dat_tbls.pdf

Utah DEQ. (2013). Department of Environmental Quality. Utah electronic e-waste education program. Retrieved on November 1, 2013, from http://www.deq.utah.gov/Pollution_Prevention/electronics.htm

Utah DEQ. (2014) Utah Department of Environmental Quality. http://www.deq.utah.gov/

WI-DNR. (2013, December). E-Cycle Wisconsin 2013 Report. Wisconsin Department of Natural Resources (DNR). Retrieved on Febraury 21, 2014, from http://dnr.wi.gov/files/pdf/pubs/wa/wa1672.pdf

Yin R.K. (2014). Case study research: Design and methods (5th ed.). Thousand Oaks, CA. Sage Publications.

Footnotes

1. Rules applied to CRTs include: 1) Intact CRTs require notification sent to EPA 60 days prior to export; 2) Broken CRTs require consent from importing country and notification sent to EPA 60 days prior to shipment; 3) Processed CRT glass documentation must how glass is being sent to lead smelter or CRT glass maker: and 4) No stockpiling of CRT glass for longer than one year (U.S., EPA, 2013).
2. Note: Population density compared to collection locations was not considered.

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Appendix A

Table 12
Health Impacts From Exposure to Heavy Metals

*HEWs	Types of Exposure	Acute Symptoms	Chronic Symptoms	Toxic Concentration
Beryllium	• Inhalation • Skin contact	• Cough • Shortness of breath • Fatigue • Weight loss • Fever • Rash	• Lung cancer • Skin bumps • Poor wound healing	$\geq$2 mg/m^3
Cadmium	• Inhalation	• Pneumonitis	• Lung cancer • Kidney damage	15µg/dL (blood)
Lead	• Inhalation • Ingestion • Skin contact	• Nausea • Vomiting • Headache • Seizures	• Encephalopathy • Anemia • Abdominal pain • Nephropathy • foot-drop/wrist-drop	5 µg/dL (Blood)
Mercury	• Inhalation • Skin contact	• Nausea • Vomiting • Fever • diarrhea	• Nausea • Metallic taste • Gingivo-stomatitis • Tremor • Neurasthenia • Nephrotic syndrome • Hypersensitivity (Pink disease)	10 ug/L (whole blood); 20 µg/dL (24-h urine)

Note. Toxic materials found in some electronic devices, and the health issues caused by prolonged exposure when handled unsafely. * Hazardous Electronic Waste (HEWs) Information from the Center of Disease Control (CDC, 2014).

Appendix B

Table 13
U.S States with Landfill Bans

State	Tracked Electronics Banned From Landfill	Additional Items	Effective Date
Arkansas	Computer and Electronic Equipment		1-1-2010
California	Desktop, Laptops, CRT TV, CRT Monitor, Flat Panel TVs, Flat Panel Monitors, Printers	Cash Registers, Peripherals, Telephones, Answering Machines, Radios, Stereos Equipment, Tape Players/Recorders, Phonographs, Video Cassette Players, CD Players, Calculators and some appliances	2/1/2006
Colorado	Computers, peripherals, Printers, Fax Machines, DVD/VCR, Any > 4"screens Video Display Device including: Computer Monitors, Laptop Computers (incl. Netbooks, Ultrabooks, etc), Tablets, E-Readers, TVs		7-1-2013
Connecticut	Desktops, Laptops, CRT TV, CRT Monitors, Flat Panel TVs, Flat Panel Monitors		1-1-2011
Illinois	Desktops, Laptops, CRT TV, CRT Monitors, Flat Panel TVs, Flat Panel Monitors, Printers		1-1-2012
Indiana	Desktops, Laptops, CRT TV, CRT Monitors, Flat Panel TVs, Flat Panel Monitors	Fax, DVD, VCR, Computer Peripherals	1-1-2011
Maine	CRT TVs, CRT Monitors	Mercury added products including mercury-added lamps	7-20-2006
Massachusetts	CRT TVs, CRT Monitors		4-1-2000
Minnesota	CRT TVs, CRT Monitors		7-1-2006
New Hampshire	Laptops, CRT TVs, CRT Monitors, Flat Panel TVs, Flat Panel Monitors		7-1-2007
New Jersey	Desktops, Laptops, CRT TV, CRT Monitors, Flat Panel TVs, Flat Panel Monitors		1-1-2001
New York	Desktops, Laptops, CRT TV, CRT Monitors, Flat Panel TVs, Flat Panel Monitors	Keyboard, Mice	1-1-2012
North Carolina	Desktops, Laptops, CRT TV, CRT Monitors, Flat Panel TVs, Flat Panel Monitors	Keyboard, Mice	1-1-2012
Oregon	Desktops, Laptops, CRT TV, CRT Monitors, Flat Panel TVs, Flat Panel Monitors		1-1-2010

Pennsylvania	Monitor, Flat Panel TVs, Flat Panel Monitors		1-1-2012
Rhode Island	Desktops, Laptops, CRT TV, CRT Monitors, Flat Panel TVs, Flat Panel Monitors		1-1-2008
South Carolina	Desktop Computers, Notebook Computers, Computer Monitors, Printers, TV,	Keyboard (or other devices sold exclusively for use with a computer)	7-1-2011
West Virginia	Computers, Computer Monitors, (all types), CRTs, DVD Players, TVs (all types), Printers (incl. toners), Video Display Devices with > 4" screens	Fax Machines, Peripherals, Keyboards, Mice, Telephones, VCR's Digital Converter Boxes, Answering Machines, Electronic Game Consoles, Stereo Equipment, E=Device Power Cords & Chargers, Wireless Cell Phones, PDA's MP3 Players and other E-Devices	1-1-2011
Wisconsin	Desktops, Laptops, CRT TV, CRT Monitors, Flat Panel TVs, Flat Panel Monitors, Printers	Keyboards, Fax, DVD Players, VCRs	91-2010

Note. Data retrieved from Electronics Recycling Coordination Clearinghouse (ERCC, 2013).

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