Waste Management 33 (2013) 519–529

Contents lists available at SciVerse ScienceDirect

Waste Management

journal homepage: www.elsevier.com/locate/wasman

Time bomb or hidden treasure? Characteristics of junk TVs and of the US households who store them

Natalia Milovantseva [a,1], Jean-Daniel Saphores [b,*]

[a] School of Social Ecology, University of California, Irvine, CA 92697, USA
[b] Civil and Environmental Engineering, Economics, and Planning, Policy, & Design Departments, University of California, Irvine, CA 92697, USA

ARTICLE INFO

Article history:
Received 1 April 2012
Accepted 12 July 2012
Available online 11 August 2012

Keywords:
e-Waste recycling
Televisions
Count models

ABSTRACT

Within the growing stockpile of electronic waste (e-waste), TVs are especially of concern in the US because of their number (which is known imprecisely), their low recycling rate, and their material content: cathode ray tube televisions contain lead, and both rear projection and flat panel displays contain mercury, in addition to other potentially toxic materials. Based on a unique dataset from a 2010 survey, our count models show that pro-environmental behavior, age, education, household size, marital status, gender of the head of household, dwelling type, and geographic location are statistically significant variables for explaining the number of broken or obsolete (junk) TVs stored by US households. We also estimate that they are storing approximately 84.1 million junk TVs, which represents 40 pounds of scrap per household. Materials in each of these junk TVs are worth $21 on average at January 2012 materials prices, which sets an upper bound on collecting and recycling costs. This information should be helpful for developing more effective recycling strategies for TVs in the e-waste stream.

1. Introduction

Partly driven by rapid advances in new screen technologies, the swelling stockpile of broken or obsolete televisions (herein called junk TVs) is becoming a symbol of the electronic waste (e-waste) problem. In a 2011 report, the US Environmental Protection Agency (EPA) estimated that discarded TVs and computer monitors accounted jointly for almost half (by weight) of the e-waste stream in the United States in 2009. This percentage is even higher in some states: in Washington State, for example, TVs represented 69.3% by weight of all e-waste collected in 2011 (WMMFA, 2011).

In spite of many recycling initiatives at the local, state and federal levels, the recycling rate of TVs in the United States was only 17% of the units ready for end-of-life management in 2009 (EPA, 2011). This is a cause for concern because improperly discarded cathode ray tube (CRT) TVs and computer monitors are a major source of lead, and flat panel (FP) as well as rear projection (RP) TVs are sources of mercury (Lim and Schoenung, 2010). According to EPA (2011), residential users were storing 104 million TVs in 2009, but this estimate is highly uncertain because it relies on a series of assumptions, including annual sales data, assumed useful life of TVs, and collected quantities reported by recyclers - a “top-down” approach.

In this paper, we rely instead on a “bottom-up” approach. Our results are based on a 2010 random survey of a large panel of households representative of the US population, whom we asked about the size, technology, and age of each junk TV they have in storage. This detailed information allowed us to estimate the amount and the value of materials in these TVs. In addition, we estimated count models to link the number of broken or obsolete TVs stored by our respondents to their socio-economic characteristics, their environmental beliefs, and to an index of environmental activism, both in total and by TV age category. Knowing the number of junk TVs stored by households and their material content is necessary to design and finance recycling programs that protect public health and environmental quality, but also to collect strategically important materials present in TVs in small amounts. Knowing how long households keep their TVs is also necessary for life cycle analyses of consumer products.

Our work complements Saphores et al. (2009) who quantified the number of large (>10 pounds) and small (⩽10 pounds) broken or obsolete electronic devices stored by US households based on a 2006 survey. They found that, on average, each US household stored 4.1 small and 2.4 large broken or obsolete electronic items but they acknowledged that their findings were likely underestimates, partly because of the broad scope of their questions, which may have been burdensome for some respondents.

Although the management of TVs in the e-waste stream is a global problem (Poon, 2008), it is compounded in the United States by the current legislative patchwork, by limitations of current

* Corresponding author. Tel.: +1 949 824 7334.
E-mail addresses: nmilovan@uci.edu (N. Milovantseva), saphores@uci.edu (J.-D. Saphores).
[1] Tel.: +1 949 824 3273.

0956-053X/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.wasman.2012.07.020

recycling policies, and by the 2009 federally-mandated transition to digital television, which led many households to replace functioning analogue TVs with digital units (FCC, 2009). Prioritizing the proper disposal and sound recycling of TVs is important for protecting public health and the environment not only at home but also abroad, where many old TVs are exported.

In the next section, we provide some background on TV recycling and briefly review some recent papers that deal with the backlog of e-waste, the material composition of TVs and challenges associated with their recycling; for brevity, we do not review the recycling literature (even though it informs our count models) because it was recently reviewed in Saphores et al. (2012). In Section 3, we explain how our dataset was collected and summarize some of its key features. In Section 4, we introduce our methodology. In Section 5, we discuss our results and in Section 6 we summarize our conclusions.

2. Background and literature review

2.1. Background on TV technologies and materials

Three main TV technologies are currently in use in US households: (1) cathode ray tube (CRT) TVs, which became popular in the 1960s; (2) rear projection (RP) TVs, which were developed to overcome screen size limitations inherent to CRT technology (Benson, 1992); and (3) flat panel (FP) TVs, which started dominating the consumer market in 2006. FP TVs include different screen technologies including plasma, liquid crystals, and now light-emitting diode displays. This sub-section focuses first on the potential toxicity of materials in TVs, before exploring the potential value of some of these materials.

2.1.1. Toxic materials in broken and obsolete TVs

All TVs contain flame retardants and heavy metals such as lead (Pb), mercury (Hg), cadmium (Ca), and chromium (Cr), which are bioaccumulative and have well researched effects on human health (ATSDR, 2008a,b, 2007); see Lim and Schoenung (2010), or Matsuto et al. (2004) for potentially toxic materials commonly found in TVs. Chromium IV is a known human carcinogen, while lead and cadmium are probable carcinogens, and mercury is a possible human carcinogen (EPA, 2012). In addition, there are growing concerns about the potential health risks of flame retardants used in plastic components of TVs (Tseng et al., 2008).

Concerns about junk TVs stem from the prospect of improper end-of-life disposal and treatment leading to the release of hazardous materials that may compromise environmental quality and human health (Jang and Townsend, 2003). The low collection rate of TVs points to a high probability of storage and improper disposal so it is important to characterize the potentially toxic materials in these units; see Socolof et al. (2005) for a synthesis of US studies, and UNU (2008) for an evaluation of the situation in the European Union.

The amount of potentially toxic materials in a TV depends on its size, but also on its technology and on its year of manufacture. For CRT TVs, for example, the main public health concern is the high lead content of their vacuum glass tube, which is on average 60% of the weight of a CRT TV (Panasonic, 2012). Even the material content of CRT glass depends on production year, screen type, and manufacturer (Andreola et al., 2005). For FP and RP TVs, however, the main health concern is mercury, which can be found in the backlighting system of liquid crystal display (LCD) TVs or in the mercury lamps of RP TVs (Benson, 1992); liquid crystals are also of concern for LCD TVs (Kirsch, 2004). As a result, FP TVs have been found to have a similar ecotoxicity potential as CRT TVs (King County Solid Waste Division, 2007).

Toxic materials can be released from discarded TVs in a variety of ways, including during careless transportation and storage (Mear et al., 2006), rudimentary disassembly, uncontrolled incineration (Gullett et al., 2007), or from leaching landfills (Jang and Townsend, 2003). These releases can then pollute air, water, and soil – the main pathways of human environmental exposure (Nieuwenhuijsen and Brunekreef, 2008).

2.1.2. Broken and obsolete TVs as resources

Broken and obsolete TVs should also be considered a resource because they contain a number of valuable materials, which can be grouped in three categories: (1) precious metals such as silver (Ag), gold (Au) and palladium (Pd); (2) base metals such as aluminum (Al), bismuth (Bi), iron (Fe), copper (Cu), nickel (Ni), tin (Sn), and zinc (Zn); and (3) traces of rare materials such as europium (Eu), yttrium (Y), and indium (In) (van Schaik, 2011).

First, we note that a substantial percentage of the annual US consumption of some of these materials in 2011 was used for manufacturing electronic and electrical products, including 29% for tin, 23% for copper, 12% for nickel, 8% for aluminum, and 7% for gold (USGS, 2012).

Second, some of these materials have a strategic dimension. The US Department of Energy identified europium and yttrium (both of which are used in traces in most TVs), as well as indium (which is used in LCD screens) as critical or near-critical materials to the US economy due to supply risks and to their importance for producing renewable energy (USDOE, 2011). We also note that in 2011 the US imported 100% of the indium and yttrium, and over 85% of the bismuth, platinum and antimony it consumed (USGS, 2012).

Third, recycling metals in e-waste would reduce the environmental footprint of metals extraction (Huisman et al., 2004).

References we consulted to estimate the amounts of materials in TVs (e.g., UNU, 2008; King County Solid Waste Division, 2007; and RIS International, Ltd., 2003) highlight the difficulty of characterizing the material composition of e-waste because of variability in product design, the proprietary composition of components, the shrinking life-span of electronic products, and developments in material science. These limitations should be kept in mind when considering our estimates of materials in broken or obsolete TVs stored by US households.

2.2. E-waste inventory estimates

Accurate e-waste inventories are essential for designing sound and comprehensive e-waste management plans. However, the academic literature acknowledges high levels of uncertainty in common modeling assumptions about the characteristics of recycled TVs and their rate of replacement (Nnorom et al., 2011; Widmer et al., 2005).

With a few exceptions (Saphores et al., 2009; UNU, 2008), studies concerned with the stockpile of e-waste were conducted on a regional scale (e.g., Florida Department of Environmental Protection, 2003; Leigh et al., 2007; Massachusetts Department of Environmental Protection, 2000) and relied on sales data, estimates of product life-span, assumptions about consumer behavior, material flow analysis, or surveys of recyclers (e.g., see EPA, 2011, 2008, 2007; Yu et al., 2010; Zhang et al., 2011 and the references herein). However, estimates based on sales statistics and life-cycle analyses usually fail to account for consumers' tendency to keep old electronics (Macauley et al., 2003). Moreover, little is known about the time lag between the moment a device becomes obsolete to its owner and its actual disposal (Linton et al., 2005).

One notable exception is a review of the European Union's Waste Electrical and Electronic Equipment (WEEE) Directive (UNU, 2008). It analyzed the collection and treatment of ten categories of products using national and industry sales data, a UK