

CATHODE RAY TUBE MANUFACTURING AND RECYCLING: ANALYSIS OF INDUSTRY SURVEY

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Introduction

Recycling end-of-life electronics is an important and growing issue facing the electronics industry. Public awareness of the issue is rising, largely because it continues to draw significant media attention and is the subject of increased local, state, federal and international regulation. These developments pose new challenges for the electronics industry and require company, as well as industry-wide, responses. At the same time, these developments provide an opportunity for the industry to inform lawmakers and the public about the electronics industry's accomplishments and efforts to address issues related to the management of end-of-life electronics.

This paper summarizes the findings of a survey conducted by the Electronic Industries Alliance ("EIA") that evaluated the current volume of manufacturing and recycling of Cathode Ray Tube ("CRT") glass by the United States ("U.S.") CRT glass manufacturers. The purpose of this paper is to evaluate the survey findings and determine if the CRT glass manufacturing industry has the capacity to absorb an increased volume of recycled glass that may result from efforts at the federal and state level to increase collection of CRTs.

I. Background

Regulations and collection programs currently exist and are being developed to increase the amount of end-of-life CRTs recycled into new CRTs. These regulations and collection programs assume that the U.S. CRT glass manufacturers have the capacity to process the increased volume of recycled CRT glass. This study evaluates whether the CRT glass manufacturers have the capacity to utilize the amount of CRT glass that these programs may generate. CRT glass manufacturers support efforts to increase the collection and recycling of CRTs and want to increase their use of recycled CRT glass in the manufacturing of new CRTs. But as this survey reveals, for the time being, their capacity is technologically limited.

This paper seeks to: 1) forecast the potential increased volume of CRT glass that may result from the Glass-to-Glass Rule and the development of electronics recycling programs; 2) evaluate what portion of this volume the CRT glass manufacturers could use as recycled glass; and 3) given the results of 1) and 2), determine whether the CRT glass manufacturers will be able to absorb the increased volume of CRT glass so as to make collection

programs and regulatory changes effective at meeting their goals.

A. GLASS-TO-GLASS RULE

The regulation that may have the most impact on CRT glass manufacturers is the United States Environmental Protection Agency's ("EPA") proposed CRT Glass-to-Glass Rulemaking ("Glass-to-Glass Rule"). The Glass-to-Glass Rule embodies the suggestions of the Common Sense Initiative's Computers and Electronics Subcommittee, which are consensus-based negotiated recommendations from a council of interested stakeholders (manufacturers, recyclers, local, state, and federal government, environmental groups). EPA has stated that the proposed rule will be published this fall, however, the proposal already has been delayed several times. The Glass-to-Glass Rule is expected to reduce some of the regulatory controls imposed on CRTs that are transported for recycling into new CRT glass. The purpose of the Glass-to-Glass Rule is to reduce the cost of CRT recycling, thereby encouraging the recycling of used CRT glass.

For example, in some cases, CRTs may be subject to hazardous waste regulation under the Resource

Conservation and Recovery Act ("RCRA"). The proposed EPA Glass-to-Glass Rule would regulate CRTs under the Universal Waste Rule ("UWR"), which would impose reduced regulatory burdens on used CRT-containing devices (e.g., computer monitors and televisions) transported for recycling into new CRTs. Under the Glass-to-Glass Rule, after CRT glass is separated from the housing of CRT-containing devices, the glass is exempted from the requirements of the UWR. The Glass-to-Glass Rule may not affect the current regulatory status of processed post-consumer CRT glass, as processed post-consumer CRT glass is arguably a non-regulated material used directly as a raw material in a production process. At the present time, although there are many alternatives for CRT recycling, the UWR's reduced regulatory requirements for CRTs do not apply if the glass is being shipped for recycling for any use other than new CRT glass. The Glass-to-Glass Rule specifically seeks to encourage the recycling of used CRT glass into new CRT glass. Thus, the reduced regulatory burdens are granted only when the glass is recycled into new CRT glass. The CRT glass manufacturers support EPA's Glass-to-Glass initiative but also favor expanding the reduced regulatory requirements for transportation of CRTs for all recycling purposes. As demonstrated in this paper, EPA's goal of recycling all used CRT glass into new CRT glass may not be entirely feasible and a broader rule may be more effective.

B. LIMITS TO CRT RECYCLING

For the Glass-to-Glass Rule to successfully meet its goal of recycling used CRT glass into new CRT glass, the glass industry must have the capacity to process the anticipated increased volume of CRT glass. However, the manufacturing of CRT glass is a very complicated and delicate process, which requires precise knowledge regarding the quantity and quality of materials used in the production process. CRT glass manufacturers have confidence in the properties of the raw materials used in traditional CRT glass manufacturing. However, using recycled glass from used CRTs poses some risk because the exact composition of the recycled glass is difficult to determine. The risk involved using glass with an unknown composition is that a small amount of the wrong compound can contaminate the contents of an entire furnace of glass. If this happens, production may have to shut down for a period of several hours to several days. There is no available technology that provides an effective and economical method for the CRT glass manufacturers to determine

the composition of recycled glass. Therefore, due to the potential risk of adding recycled glass with the wrong composition, CRT glass manufacturers have a limited capacity to increase the use of recycled glass in lieu of raw materials to manufacture new CRTs.

II. Project Scope and Description

Last August, representatives of the CRT glass manufacturing industry requested that EIA investigate the impact of the Glass-to-Glass Rule as well as the role of CRT glass manufacturing in the broader issue of CRT recycling. The capacity of the CRT glass manufacturers to accept recycled CRT glass has not been previously assessed. Accordingly, EIA developed a survey asking the CRT glass manufacturers to share data on a confidential basis. The survey requested manufacturers to report their total sales of CRT glass and total use of recycled CRT glass from outside sources for the last ten years. EIA also requested that CRT glass manufacturers share the criteria currently used for accepting recycled CRT glass and what amount of recycled CRT glass they speculate could be used if better technology were available for classifying CRT glass. It was a significant effort for the CRT glass manufacturers to share this information because it is highly guarded and confidential. EIA acknowledges and appreciates the efforts of the CRT glass manufacturers to share this information with the industry.

EIA collected data to determine the volume of CRT glass sold in North America over the last 10 years. To obtain these numbers, EIA collected all statistics on sales of CRTs in the United States including imports and exports. The information for television sales was obtained from EIA's partner associations, the Consumer Electronics Association and the Electronic Components, Assemblies, and Materials Association. The information for monitor sales came from Stanford Research, Inc.

The data collected was used to compare the CRT glass manufacturers capacity to use recycled CRT glass with the potential volume of CRT glass that may be collected as a result of the Glass-to-Glass Rule and other end-of-life electronics recycling initiatives.

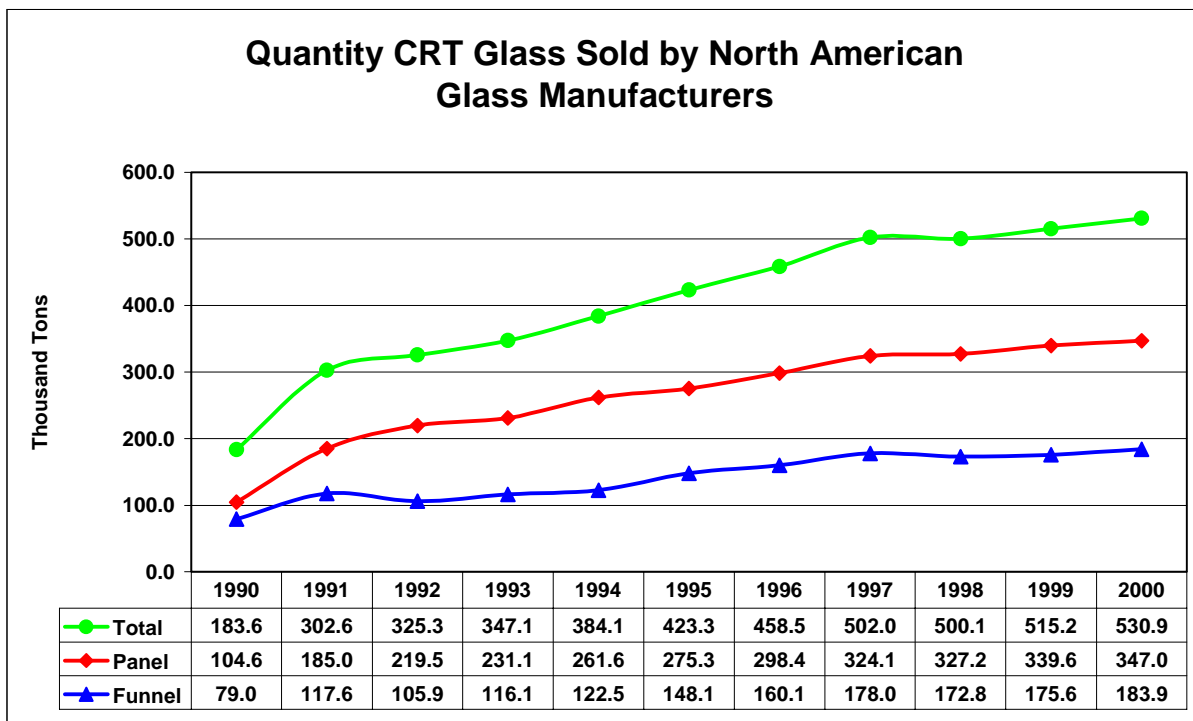
III. Survey Results

The following is a brief summary of EIA's survey results from the four CRT glass manufacturers. Complete Survey results are included as Attachment A.

A. QUANTITY OF CRT GLASS SOLD BY NORTH AMERICAN DEALERS

The survey shows that the amount of CRTs sold has increased substantially over the last ten years. The type of CRT glass sold is divided into three categories: leaded panel glass, no-lead panel glass, and funnel glass. Only one U.S. CRT glass manufacturer currently produces leaded panel glass that contains approximately 2.0-2.3 percent lead. The three other U.S. CRT glass manufacturers produce no-lead panel glass. The funnel glass is produced by all four CRT glass manufacturers and has approximately the same composition.

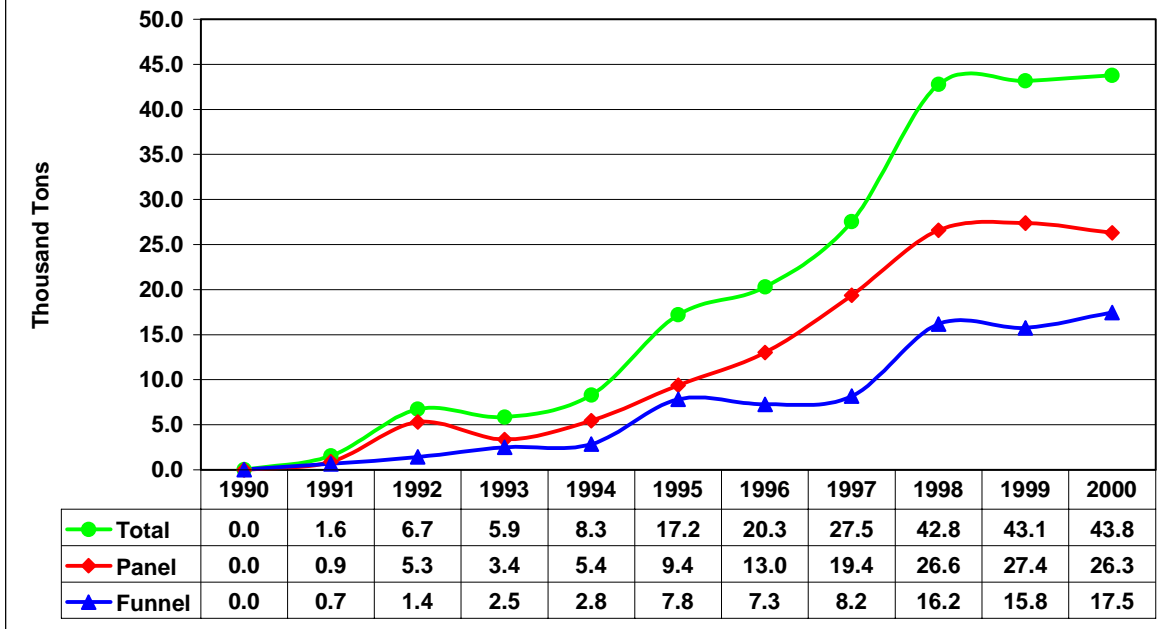
The amount of leaded glass panel increased between 1990 and 1998, from 74,461 tons to 109,731 tons, but decreased in 1999 to 95,124 tons and to 90,640 tons in 2000. The amount of no-lead panel glass sales increased more dramatically in the same time period, from 30,137 tons in 1990 to 256,358 tons in 2000. The significant increase in no-lead panel sales represents the conversion of three glass manufacturers from leaded panel production to no-lead panel production. Funnel glass sales increased from 78,967 tons in 1990 to 183,906 tons in 2000. This is a total increase of CRT glass sales of 183,565 tons in 1990 to 530,904 tons in 2000. The volume of CRT glass sales also increased due to the CRT market shift from small items (19" to 25") to large items (27" and above), depicted on this chart:



The sales of CRT glass have increased by approximately 290% since 1990. The conversion to no-lead panels by three of the four CRT glass manufacturers has reduced the total amount of lead used in the production of panel glass by 24% despite the three-fold increase in panel sales. The average CRT for the time period 1995 to 2000, including televisions and monitors, is an 18.63-inch CRT with

a lead content that varies from 2.14 lbs to 2.63 lbs. Details are included as Attachments B: Average Lead in a CRT, and Appendix C: Average CRT Size. The CRT glass industry's ability to limit the use of lead in the manufacture of new CRTs is a significant contribution to the electronic industry's overall effort to reduce the use of substances of concern, and therefore the environmental impact of electronics

Recycled Cullet Used in North America



manufacturing and the recycling and disposal of end-of-life electronic products.

cullet will not be considered recycled cullet for this report.

The CRT glass manufacturers' shift to producing no-lead panels affects the recycling capacity of the industry. No-lead panel glass can be reused in the manufacture of leaded and no-lead panel glass and, in limited quantities, in the manufacture of funnel glass. Leaded glass (funnel and leaded panel) can be used to manufacture leaded panel and funnel glass but cannot be used to make no-lead panels. Thus, the one manufacturer of leaded panel glass has a greater ability to use older CRTs manufactured with leaded panel glass.

Recycled cullet includes glass returned from outside sources to the CRT glass manufacturers. CRT glass is shipped to CRT tube manufacturers and, in assembling CRT tubes, a substantial volume of CRT glass is broken. For many years the CRT tube manufacturers disposed of the broken glass, also called cullet. Now the universal practice is to send the cullet back to the CRT glass manufacturers for recycling. CRT glass manufacturers have a high degree of confidence as to the composition of this recycled cullet since they know the glass was produced by their facility. The CRT glass manufacturers are recycling most, if not all, of this recycled CRT cullet.

B. VOLUME OF RECYCLED CULLET

In discussing the volume CRT recycled glass, it is important to clearly define the term "recycled." The reuse of glass within a CRT glass manufacturing plant is part of the normal operation of the facility. This reused glass is generated because the CRT glass manufacturers process a large amount of glass that cannot be sold due to breakage or flaws in the glass. The term for this glass is cullet. The defective cullet is reused to form new glass and has historically been considered a raw material by the industry. The percentage of cullet used in CRT glass manufacturing has historically been between 30% and 80%. This

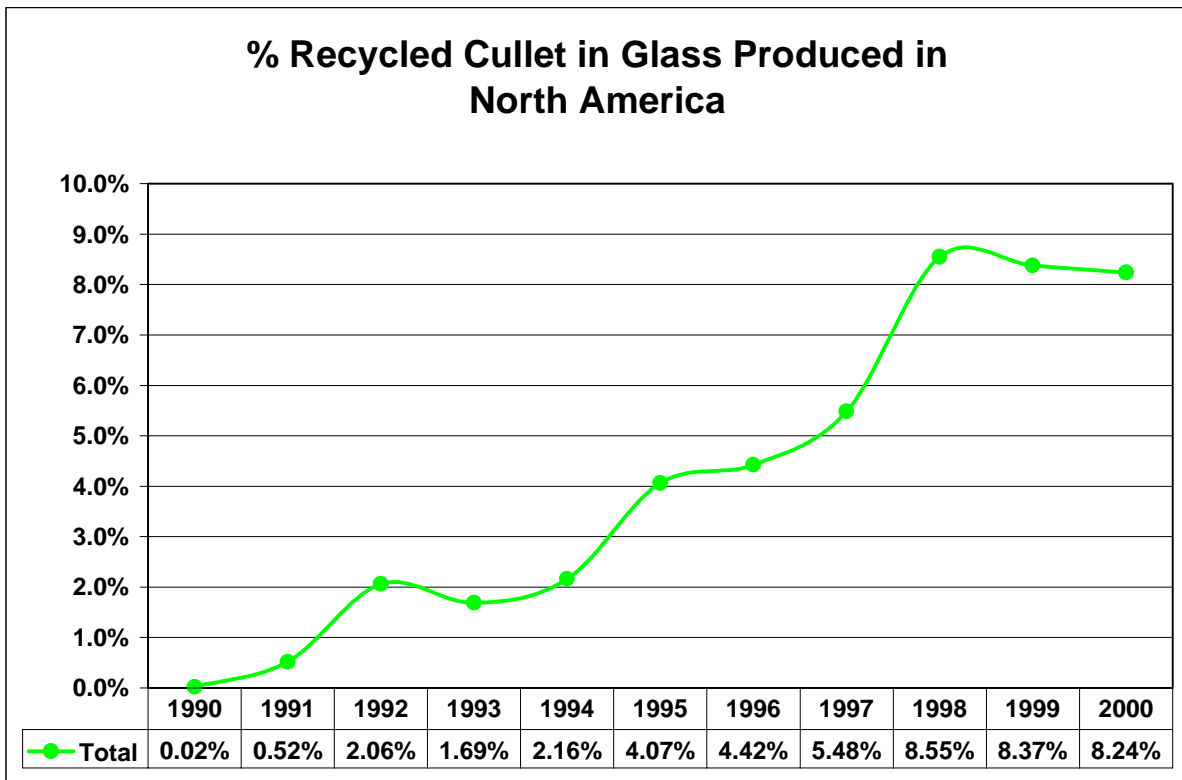
Processed post-consumer cullet is also considered recycled cullet received from outside sources. Post-consumer cullet is glass that was originally sold as CRT glass in a television, monitor, or other CRT-containing device and returned to the recycler when the device reaches its end-of-life. Only in recent years have some CRT glass manufacturers begun to receive post-consumer CRT glass from CRT glass recyclers. The amount of post-consumer cullet recycled is currently a small percentage of recycled CRT glass.

It is not possible to separate the post-consumer cullet from the cullet received from CRT tube manufacturers. This information was not requested in EIA's survey because currently the CRT glass manufacturers do not record it. The percent varies for each company, but all agree that the CRT tube manufacturers supply much more than half of the recycled cullet.

Survey results show that the amount of recycled cullet received from outside sources has increased dramatically over the last ten years. The chart below highlights that, in 1990, the CRT glass manufacturers used only 40 tons of recycled cullet. In 2000, a total of 43,759 tons was used including 17,466 tons of funnel glass, 8,431 tons of leaded panel glass and 17,862 tons of no-lead panel glass. The graph below

shows that CRT glass manufacturers have steadily increased the volume of recycled cullet used over the last ten years. The increased recycling of cullet is another positive effort that the glass industry has contributed to the life-cycle management of electronics.

Yet, when the total tons of recycled cullet are converted into the percentage of total glass produced, it is interesting that in the last year, the percent of recycled cullet used in the manufacturing of new CRT glass has decreased.



There are a few reasons for this decline. The majority of the recycled cullet is received from CRT tube manufacturers. This source of recycled cullet was maximized several years ago (around 1996). Since then, the CRT tube manufacturers have implemented more efficient technology, which reduces the breakage of CRT glass. As a result, they ship less recycled cullet back to CRT glass manufacturers. At the same time, there has been little

technological improvement to increase the recycled cullet received from post-consumer recyclers to offset the reduction in recycled cullet supplied by the CRT tube manufacturers.

C. TECHNOLOGY ISSUES

The survey also asked manufacturers to report their current standards or what technology their plants employ to evaluate whether recycled cullet is

acceptable. These standards show that there is no uniform or simple way to assess recycled cullet and that manufacturers have little certainty as to the composition of the recycled cullet. The survey also asked the manufacturers to speculate as to the amount of recycled cullet they could accept if improved technology was available to analyze the composition of the cullet more accurately.

1) Current Criteria for Accepting Cullet

The EIA survey illustrated that currently there is no standard measure for accepting recycled cullet. Manufacturers are able to accept more funnel glass because of its uniform composition. Three of the companies accept funnel glass with a mix of 10% panel glass. One company reported it accepts pieces of neck and stem (other highly leaded CRT parts) included in "funnel" glass. For funnel glass, all companies reported they would not accept glass that has traces of metals or metal parts, foreign materials such as wood, plastics, paper, oils, coatings, ceramic contaminants.

For panel glass, one company requires that the glass be of a non-lead composition, and not contaminated with metal parts, ceramics, frit or coatings. The second company requires a minimum of 95 percent panel (maximum 5 percent funnel glass). It also requires that glass be clean of frit or neck glass and foreign materials, and that broken glass be of at least a minimum size. The third company requires that the glass be of homogeneous composition and only be glass from television CRTs. The fourth company requires that the glass is clean and free of foreign materials including frit, funnel or leaded panel glass.

No manufacturer requires information regarding the composition of the glass that would provide accuracy as to the effect of adding post-consumer recycled cullet to the new glass manufacturing process. Hence, with unspecific content and quality information, the manufacturers are limited by the amount of recycled cullet that they can safely add to their glass production.

CRT glass manufacturers also require a reliable, consistent supply of recycled cullet from recyclers. By its nature, the supply of end-of-life electronics is inconsistent. Recyclers have no control over the age, type and quantity of used CRT devices that they receive. Until an infrastructure is in place for recycling CRTs, the inconsistency of the supply will continue. The need for a consistent supply is why the

CRT glass manufacturing industry is supportive of reduced regulatory controls, such as those proposed in the Glass-to-Glass Rule. The CRT glass manufacturers participated in this survey to assess their ability to absorb the projected volume of CRT glass and to demonstrate that better glass sorting technology is needed to achieve greater recycling of used CRT glass.

2) Capacity with Current Technology

Using the present recycling system, CRT glass manufacturers reported that the industry could use 125,100 tons of recycled cullet. The majority of this, 61,500 tons, is funnel cullet because it is the most uniform in composition and thus poses less risk of adding unwanted properties to the new CRT glass manufacturing process. CRT glass manufacturers reported they could use 16-17,000 tons of leaded panel and 46,600 tons of no-lead panel. These estimates show that the potential for the CRT glass manufacturers to use recycled cullet is well above the current volume of recycling.

3) Capacity With New Technology

Every CRT glass manufacturer responded that, if better technology were available to sort the recycled cullet, they could further increase their use of recycled cullet. The CRT glass manufacturers indicated that their projected increases are conservative estimates. The industry is not willing to commit to increasing its use of recycled cullet content in CRT glass because it is entirely uncertain that the technological limitations can be overcome.

However conservative the estimates, with better sorting technology, the amount of recycled cullet that CRT glass manufacturers accept could increase from 125,000 to 161,600 tons per year. The increase will primarily occur in the category for reuse as no-lead panel. Better glass sorting technology would provide manufacturers with confidence that the recycled panel cullet does not contain lead, thereby allowing larger quantities to be accepted. The amount that could be recycled beyond that projected by the manufacturers is speculative, but it is clear that the volume that could be recycled will increase with improved technology.

IV. Research Statistics for End-of-Life Electronics

A. CALCULATION OF THE CURRENT VOLUME OF END-OF-LIFE ELECTRONICS

The potential amount of end-of-life CRTs which are available to be recycled through collection under new regulations can be estimated based on the sales of CRTs in North America over the last ten years. There is limited certainty in the correlation between the sales of CRTs and the amount available for recycling. In fact, some of the CRTs sold over the last ten years may have already been recycled or disposed. However, there are also CRTs that were sold ten to thirty years ago that have not been disposed or recycled. These remain in use or in storage and will be recycled or disposed in the future. (According to the statistics gathered by the Minnesota Pilot Project, half of the electronics products collected were older than 10 years.) CRTs which are older than ten years but have not been disposed may roughly offset those CRTs sold in the last ten years but will not be disposed for several years to come. This is a rough approximation and not entirely accurate, but for the purpose of this study it is accurate enough to compare the capacity of the CRT glass manufacturers to the potential quantity of recycled cullet. Furthermore, it is likely that the majority of the CRTs sold in the last ten years have

not reached their end-of-life. Thus, this figure is at least representative of a minimum volume of potential cullet available for recycling.

There is no accurate record of how many CRTs have already reached end-of-life recycling or disposal. There are a variety of statistics cited as the volume of end-of-life electronics in the U.S. The most commonly cited statistic is the National Safety Council's *Electronic Product Recovery and Recycling Baseline Report*. Other groups, such as the Silicon Valley Toxics Coalition, state that the volume of end-of-life electronics is even higher. The bottom line is that none of these statistics is accurate because the data for how many CRTs have been recycled or disposed have not been recorded.

B. CRT SALES DATA

The sales data for CRTs in North America are composed of television and monitor sales. The total television sales in 1991 were 19,474,018 units and by 2000 sales reached 24,174,000 units. The monitor sales figures are only available from 1995 as data was not tracked or recorded by the industry in earlier years. The monitor sales for 2000 are 52,100,000 units.

CRT's Sold by North American Dealers (Thousand Units)										
	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Size Category	Portable and Table									
8" and Under	200	200	9-10" ¹	200	9-10"	100	100	9-10"	9-10"	13-14"
9" & 10"	300	300	500	400	500	400	300	400	400	13-14"
13" & 14"	3,900	4,000	4,100	4,300	3,800	3,600	3,400	3,600	3,600	4,400
19"	4,000	4,200	4,800	5,500	5,300	4,800	4,700	4,900	5,500	5,700
20"	4,700	5,000	4,800	4,100	3,200	2,400	2,000	1,700	1,300	1,300
25"	1,900	2,600	3,400	4,100	4,100	26-27"	26-27"	3,600	4,000	3,800
26" & 27"	32"	32"	32"	3,900	3,900	8,300	8,100	5,000	5,200	5,300
29" - 31"	32"	32"	32"	1,200	1,200	500	300	200	32"	32"
32"	2,900	3,300	4,300	29-31"	29-31"	1,100	1,300	1,700	2,300	2,500
36"	100	200	32"	29-31"	500	600	700	800	1,000	1,200
Total	18,000	19,800	21,900	23,700	22,500	21,800	20,900	21,900	23,300	24,200
Size Category	Console									
26" and under	800	600	500	400	27-32"	27-32"	27-32"	27-32"	Included with Portable and Table	
27" - 32"	600	600	700	700	700	500	300	200		
35" and over	100	100	27-32"	27-32"	100	100	100	100		
Total	1,500	1,300	1,200	1,100	800	600	400	300		
Size Category	Monitors									
14" & Under	Data Not Available				7,400	7,300	4,100	2,600	1,400	500
15"					11,600	13,300	12,800	12,900	15,700	20,000
17"					2,100	3,600	10,300	13,700	17,800	25,000

¹ Inches indicate those units are included in listed size category.

19" – 21"					300	300	1,200	2,400	4,100	6,500
Total					21,400	24,500	28,400	31,600	39,000	52,100
TOTAL CRTs	19,500+	21,100+	23,100+	24,800+	44,700	46,900	49,700	53,800	62,300	76,300

The sales data for specific types of televisions can be converted to total tons of CRT glass using the

following average glass weights.

Average Glass Weights in Pounds					
	Funnel	Panel	Neck	Frit	Total
Portable and Table					
8" /under	4.4	8.4	0.1	0.1	12.9
9" & 10"	5	9.9	0.1	0.1	15
13" & 14"	6.1	11	0.1	0.1	17.2
19"	9.2	17.6	0.1	0.1	27.1
20"	9.2	18.7	0.1	0.1	28.2
25"	13.6	29.5	0.2	0.2	43.5
26" & 27"	16.9	35.9	0.2	0.2	53.2
29" – 31"	28.2	52.6	0.2	0.3	81.2
32"	29.5	55.7	0.2	0.3	85.6
36"	39.6	77.2	0.2	0.3	117.4
Console					
26" /under	15.4	33.0	0.2	0.2	48.8
27" – 32"	22.9	45.1	0.2	0.3	68.5
35" /over	39.6	77.2	0.2	0.3	117.4
Monitors					
14"	7.0	12.5	0.1	0.1	19.7
15"	7.0	12.5	0.1	0.1	19.7
17"	8.8	16.7	0.1	0.1	25.7
19" – 21"	9.6	18.3	0.1	0.1	28.0

The total amount of CRT's sold in 2000 equals 1,145,800 tons of glass. This figure represents the amount of CRT's (television and monitors) sold in

North America whereas the survey data determines the total production of CRT glass in North America.

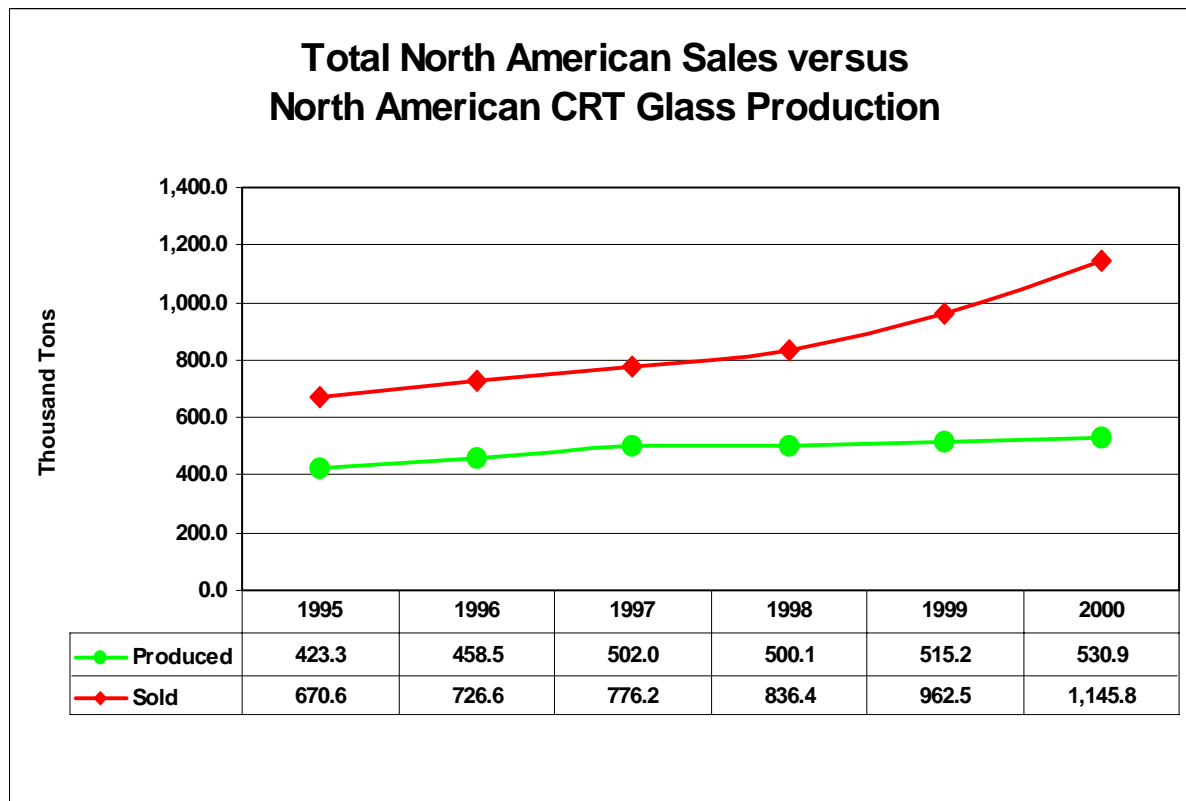
Television Sales to North American Dealers (Thousand Tons)										
	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Size Category	Portable and Table									
8" and Under	1.1	1.2	9-10" ¹	1.1	9-10"	0.9	0.6	9-10"	9-10"	13-14"
9" & 10"	2.4	2.6	3.8	2.7	3.5	2.8	2.1	3.1	2.5	13-14"
13" & 14"	33.8	34.1	35.1	37.2	32.5	31.3	29.4	30.6	31.0	38.0
19"	53.9	57.4	65.0	74.2	71.9	65.3	63.5	66.8	74.1	76.9
20"	66.7	70.6	67.6	58.0	45.4	33.1	27.6	23.8	18.1	18.6
25"	40.3	55.6	73.4	88.6	88.3	26-27"	26-27"	79.2	87.1	83.3
26" & 27"	32"	32"	32"	102.6	103.6	216.1	211.4	132.9	139.4	141.8
29" – 31"	32"	32"	32"	56.6	50.8	18.8	12.6	9.8	32"	32"
32"	123.3	139.7	187.9	29-31"	29-31"	46.4	55.6	70.8	97.0	105.0
36"	5.3	9.4	32"	29-31"	26.8	36.9	43.5	48.6	58.5	67.7
Total	326.8	370.6	432.8	421.0	422.8	451.6	446.3	465.6	507.7	531.3
Size Category	Console									
26" and under	20.4	15.5	12.9	10.0	27-32"	27-32"	27-32"	27-32"	Included with Portable and Table	

27" – 32"	21.1	21.2	24.1	23.7	22.6	16.6	10.9	6.6		
35" and over	4.1	4.9	27-32"	27-32"	7.0	5.1	3.3	1.8		
Total	45.6	41.6	37.0	33.7	29.6	21.7	14.2	8.4		
Size Category	Monitors									
14"	Data Not Available				72.8	71.9	40.4	25.6	13.8	4.9
15"					114.2	130.9	126.0	127.0	154.6	196.9
17"					27.0	46.3	132.5	176.2	228.9	321.6
19" – 21"					4.2	4.2	16.8	33.6	57.5	91.1
Total					218.2	253.3	315.7	362.4	454.8	614.5
TOTAL CRT's	372.4+	412.2+	469.8+	454.7+	670.6	726.6	776.2	836.4	962.5	1,145.8

¹ Inches indicate those tons are included in listed size category.

The following chart highlights the consistent growth of imported CRT glass into North America. In 2000,

54% of the CRT's sold (by glass weight) appear to be manufactured outside of North America.

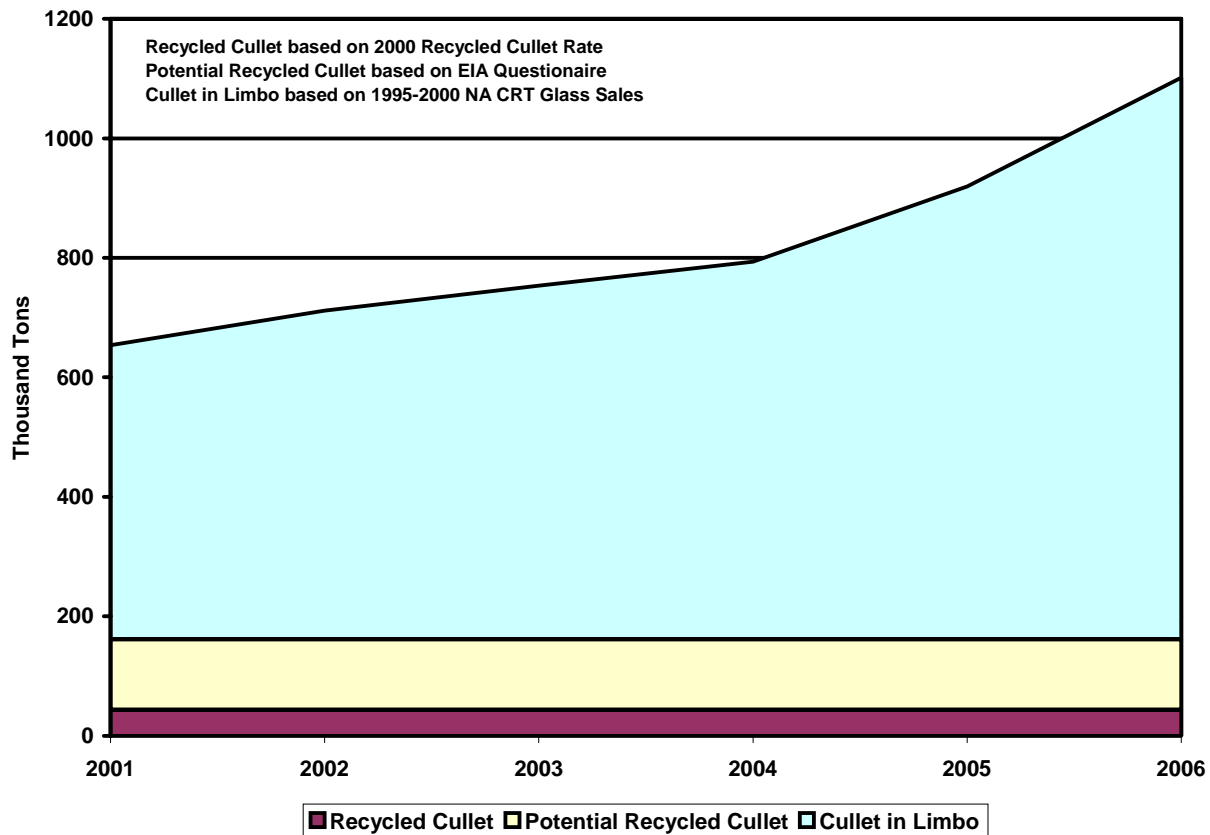


V. Conclusions

Comparing the current use of recycled cullet, the potential volume of recycled cullet, and the potential increase of available end-of-life recycled cullet, U.S.

CRT glass manufacturers do not have the capacity to absorb the total amount of recycled cullet if the widespread collection of end-of-life CRT were to begin.

CRT Sales to NA Dealers and Recycled Cullet



The above chart shows that the current amount of actual recycled cullet (from CRT tube manufactures and post-consumer CRT glass recyclers) used by the CRT glass manufacturers is very small. The potential recycled cullet is constant over the years as it is based on the approximate capacity projected by the CRT glass manufacturers. The amount of “cullet in limbo” represents the amount of CRT recycled cullet that cannot be recycled using current sorting technology. The potential amount of “cullet in limbo” for 2001 is 491,800 tons.

The amount of actual recycled cullet is far below the amount the CRT glass manufacturers have the potential to use even with existing technology. The recycled cullet currently used is mostly glass received from tube manufacturers. This glass does not pose the risks of uncertain composition because the glass manufacturers manufactured the glass and know its composition. Thus, while the CRT glass manufacturers are using recycled cullet, the technological limits on using post-consumer cullet have yet to be addressed.

The survey shows that the current criteria used to accept cullet are vague, but if post-consumer CRT glass recyclers could supply the CRT glass manufacturers with glass that meets these criteria, the CRT glass manufacturers have the capacity to use more recycled cullet. The maximum amount of potential cullet that the CRT glass manufacturers could use with current technology and criteria is 125,000 tons. This is an estimate that the CRT glass manufacturers made based on the CRT recyclers being able to provide a steady stream of clean and uniform glass. The Glass-to-Glass Rule and collection programs will help provide more CRT material to recyclers, increasing their ability to provide clean and uniform CRT cullet to the CRT glass manufacturers.

The potential recycled cullet with better technology is a flat line at 161,600 tons. This number is an estimate of how much the CRT glass manufacturers could use with technology that analyzes the CRT glass composition. Many of the CRT glass manufacturers admitted their estimate was very conservative. This is because the technology does not exist yet and manufacturers are reluctant to commit to a recycling figure that is currently impossible. With better technology the number will likely be higher than 161,600 tons.

The above graph shows that the potential CRT glass that the CRT glass manufacturers could accept with better glass sorting technology would significantly reduce the "cullet in limbo." For example, in 2001, with better sorting technology, the "cullet in limbo" would be reduced to 491,800 tons. Yet, the remaining "cullet in limbo" is still a large amount of the potentially available recycled CRT glass that cannot be used by the glass industry. The sales data shows North America consumes more CRT glass than it produces, thus it is not feasible for the U.S. CRT glass manufacturers to ever be able to absorb the full volume of end-of-life CRT recycled cullet.

Therefore, CRT glass manufacturers do not have the capacity to absorb the full volume of CRT recycled cullet that proposed regulations, such as EPA's Glass-to-Glass Rule, and new collection programs may generate. The CRT glass manufacturers remain supportive of the regulations, particularly the Glass-to-Glass Rule, in order to increase the recycled cullet available and maximize the potential amount of cullet that could be used with current technology. The CRT glass manufacturers support any program

that will help create market incentives that generate more reliable and higher quality recycled cullet.

However, the CRT glass manufacturers are also concerned that the Glass-to-Glass Rule does not provide regulatory incentives for using glass that is destined for recycling in products and processes other than new CRT glass. As currently contemplated, the Glass-to-Glass Rule anticipates that U.S. CRT glass manufacturers will be able to recycle the increased amount of glass collected and shipped for glass-to-glass recycling. As this study shows, the U.S. CRT glass industry is not the source of the entire volume of glass nor does the current technology enable CRT glass manufacturers to increase the volume of recycled cullet they can accept.

Therefore, the CRT glass manufacturers do not have the capacity to fully absorb the projected increases in the volume of CRT glass collected for recycling.

VI. Recommendations

The data reported in this paper highlights the need for CRT glass manufacturers, recyclers, state and federal regulators and the public to work together to find a use for the increased volume of CRT cullet so it can be recycled into new products, including, but not limited to, new CRTs.

Industry and government also need to find ways to promote the development of technology needed to allow recyclers to more accurately classify CRT cullet. With better classification and sorting technology, the amount of CRT cullet the CRT glass manufacturers could recycle could increase dramatically. This technology must be economical to make the use of recycled cullet competitive compared to cheaper raw materials. Some ideas for new technologies exist but a great deal of work needs to be done to develop new technologies that are economically feasible and widely available.

Finally, the industry recommends that the Glass-to-Glass Rule reduce regulatory burdens on CRT glass destined for both glass-to-glass recycling and recycling into products and processes other than CRT glass. This would provide economic incentive for other legitimate recycling efforts that could absorb some of the CRT glass that the CRT glass manufacturers cannot reuse. Such an approach would greatly increase the success and usefulness of the Glass-to-Glass Rule.

Appendix A: CRT Survey Results

1. What amount of glass was sold at your facility during the past 10 years?

Production			
Year	Leaded Panel (tons)	No-Lead Panel (tons)	Funnel (tons)
1990	74,461	30,137	78,967
1991	147,218	37,797	117,561
1992	182,221	37,242	105,863
1993	190,823	40,264	116,054
1994	188,060	73,554	122,511
1995	184,656	90,606	148,062
1996	181,104	117,299	160,104
1997	177,254	146,820	177,955
1998	109,731	217,500	172,834
1999	95,124	244,501	175,590
2000	90,640	256,358	183,906

2. What amount of cullet was received from Outside Sources during the past 10 years? (Outside Sources = Customers, Third Party Recyclers, etc.)

Cullet Received from Outside Sources				
Year	Leaded Panel (tons)	No-Lead Panel (tons)	Funnel (tons)	Mixed (Funnel & Panel)
1990	0	0	39	0
1991	317	577	666	0
1992	4,606	682	1,424	0
1993	2,274	1,091	2,495	0
1994	3,106	2,341	2,846	0
1995	1,802	7,588	7,823	0
1996	4,822	8,194	6,377	883
1997	13,313	6,045	7,063	1,107
1998	15,734	10,859	14,130	2,032
1999	12,707	14,677	15,761	0
2000	8,431	17,862	17,466	0

3. What are your current criteria for accepting cullet from Outside Sources?

Funnel
Company #1- Glass must be free of coatings, non-ferrous metal and ceramic contaminants. To be classified as "funnel" it must contain less than 10% panel by weight.
Company #2- Minimum 90% Leaded funnel glass, max. 10% panel glass. No metals or metal parts. No foreign materials such as wood, plastics, or oils. Neck/stem-tubulator/glass mixed with funnels is acceptable. Less than 10% of the surface may be covered with DAG coatings. Broken glass: 90% less than 4X4 inches. Avoid oils, chloride containing chemicals. It is acceptable to add limited amounts of anti-Freezing agents such as propylene glycol or Ice Ban™.
Company #3- 0.010-0.375" size; clean; free of non CRT glass contaminants consistent supply
Company #4- Clean conditions (cullet free of foreign materials such as plastic, wood, paper, ceramics). Frit contamination no greater than 0.005 wt.%. No more than 10% panel (leaded or non-leaded) mixture.

Panel
Company #1- Glass must be no-lead composition. Glass must not be contaminated (i.e. no metal parts, ceramics, etc.). Glass must be clean of frit and coatings.
Company #2- Minimum 95% Panel glass, max. 5% funnel glass. Clean conditions: no frit, no funnel or neck glass, no metal, no foreign materials such as wood, plastic, and oils; paper and adhesives are acceptable. Broken glass: 90% less than 4X4 inches. "FINES" to be minimized (>20 mesh). Avoid oils, chloride containing chemicals. It is acceptable to add limited amounts of anti-Freezing agents such as propylene glycol or Ice Ban™.
Company #3- Homogeneous composition: +/-0.1 std dev on 8 chem's. No non-TV glass contaminants. Consistent supply.
Company #4- Clean conditions (cullet free of foreign materials such as plastic, wood, paper, ceramics). No frit material. No funnel (or leaded panel) contamination. Transmittance separation by +/- 5%.

4. Using your present criteria, what is the maximum amount of cullet you could accept and use from Outside Sources on an annual basis?

Maximum Cullet Received from Outside Sources using present criteria			
	Leaded Panel (tons)	No-Lead Panel (tons)	Funnel (tons)
Per Year	16-17,000	46,600	61,500

5. If the cullet can be sorted by transmittancy, what is the maximum amount of cullet you could accept and use from Outside Sources on an annual basis?

Maximum Cullet Received from Outside Sources Sorted by Transmittancy			
	Leaded Panel (tons)	No-Lead Panel (tons)	Funnel (tons)
Per Year	16-17,000	46,600	61,500

6. If the cullet can be sorted by transmittancy and composition/chemistry, what is the maximum amount of cullet you could accept and use from Outside Sources on an annual basis?

Maximum Cullet Received from Outside Sources Sorted by Transmittancy and Composition/Chemistry			
	Leaded Panel (tons)	No-Lead (tons)	Funnel (tons)
Per Year	16-17,000	72,600	61,500

7. During Outside Source cullet processing there may be a stream of mixed cullet (funnel and panel) generated. What is the maximum amount of mixed cullet in tons you could accept from Outside Sources on an annual basis, if the composition was known?

Company#1	4,000 @ 50%panel
Company#2	1,000
Company#3	5,500
Company#4	0
Totals	10,500

8. Additional data or comments you feel may be useful to help promote Outside Source CRT cullet.

No Comments Given

Appendix B: Average Lead in CRT's

	Amount of Pb in a Funnel (lbs)	Amount of Pb in Pb Panel (lbs)	Amount of Pb in a Neck (lbs)	Amount of Pb in the Frit (lbs)	Total Pb in Pb Panel Set (lbs)	Total Pb in No-Pb Panel Set (lbs)
Portable and Table						
8" & under	1.0	0.2	0.027	0.057	1.30	1.08
9" & 10"	1.1	0.3	0.027	0.057	1.47	1.21
13" & 14"	1.4	0.3	0.027	0.057	1.75	1.46
19"	2.1	0.5	0.027	0.079	2.66	2.21
20"	2.1	0.5	0.027	0.086	2.70	2.21
25"	3.1	0.8	0.054	0.129	4.05	3.28
26" & 27"	3.9	0.9	0.054	0.129	4.97	4.03
29" through 31"	6.4	1.4	0.054	0.165	7.99	6.62
32"	6.7	1.4	0.054	0.186	8.39	6.94
35"	9.0	2.0	0.054	0.215	11.28	9.27
Console						
26" & under	3.5	0.9	0.054	0.129	4.54	3.68
27" - 32"	5.2	1.2	0.054	0.186	6.61	5.44
35" & over	9.0	2.0	0.054	0.215	11.28	9.27
Monitors						
14"	1.6	0.3	0.027	0.057	NA	1.68
15"	1.6	0.3	0.027	0.057	NA	1.68
17"	2.0	0.4	0.027	0.057	NA	2.08
19" through 21"	2.2	0.5	0.027	0.079	NA	2.28

Appendix C: Average CRT Size

	1995	1996	1997	1998	1999	2000
Total CRT Sales (Units)	44,631,116	46,883,300	49,693,134	53,804,322	62,218,339	76,174,000
Total CRT Viewable Inches	822,387,757	869,989,845	930,151,636	1,010,071,693	1,167,778,807	1,411,635,000
Average Set Size (Viewable Inches)	18.43	18.56	18.72	18.77	18.77	18.53
Pb Present in Pb Panel Set (lbs)	2.58	2.60	2.62	2.63	2.63	2.59
Pb Present in No-Pb Panel Set (lbs)	2.14	2.16	2.18	2.18	2.18	2.16