Preliminary Oregon E-Cycles Collections Determination for 2020

This document describes DEQ's determination of the total weight of covered electronic devices to be collected by Oregon E-Cycles recycling programs in 2020. DEQ will use this total weight to determine the minimum recycling obligation (return share by weight) for each participating electronics manufacturer for 2020.

Collections for prior years

Table 1 shows the collections determination, total weight, and pounds per capita for each year since Oregon E-Cycles operations began in 2009. Beginning in 2012, collections are shown with and without credits.[1] A recycling program obtains credits during a calendar year when the pounds of covered electronic devices collected exceed a recycling program's return share by weight obligation. The recycling credits can be used in later calendar years, if needed, to meet the recycling program's return share by weight obligation.

Table 1: Oregon Collections for 2009-2018

Year	Collections Determination^		Actual Collections (without credits)		Total Collections (with credits)		Per Capita Change from Actual Collections Prior Year
	Total Pounds	Pounds per Capita	Total Pounds	Pounds per Capita	Total Pounds	Pounds per Capita	
2009	12,210,000	3.3	19,115,790	5.00	N/A	N/A	NA
2010	21,460,000	5.8	24,150,347	6.30	N/A	N/A	26.16%
2011	22,950,000	6.0	25,885,949	6.71	N/A	N/A	6.45%
2012	27,051,000	7.1	26,670,440	6.89	28,123,134	7.26	2.65%
2013	28,641,550	7.3	27,731,429	7.06	29,668,476	7.55	2.44%
2014	29,261,460	7.4	27,429,939	6.91	29,197,113	7.36	-2.04%
2015*	30,483,254	7.62	29,420,151	7.31	30,050,559	7.47	5.76%
2016[#]	30,126,571	7.43	26,225,760	6.43	N/A	N/A	-11.99%
2017	28,000,000	6.81	24,090,120	5.82	24,654,962	5.99	-9.58%
2018	21,770,815	5.19	20,208,025	4.82	20,252,283	4.83	-17.20%
2019	17,250,000	4.05					

^Represent the values reported in each year's respective final collections determination publication
**First year for collections of printers and computer peripherals (keyboards and mice)*
[#]First year using the Oregon Office of Economic Analysis population estimate instead of the U.S. Census Bureau

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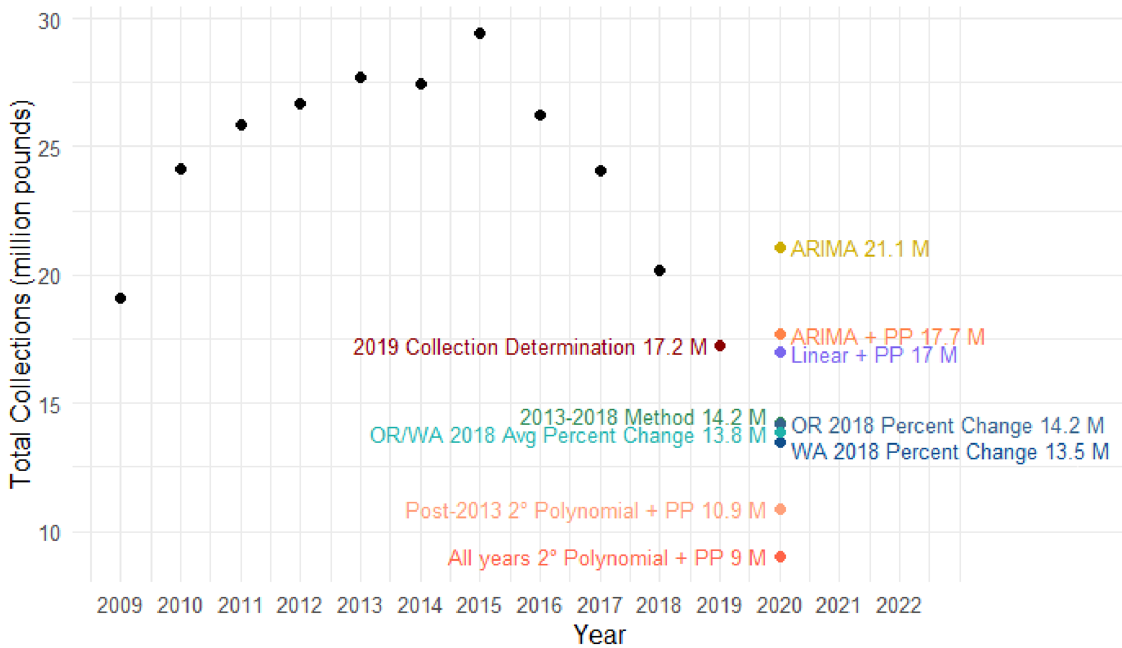
[1] Beginning in 2012, ORS 459A.322 allows Oregon E-Cycles recycling programs to use credits earned in previous years to satisfy up to 15 percent of their return shares by weight obligation for any calendar year.

Proposed Collections Determination for 2020

DEQ is proposing 13,750,000 pounds, or 3.20 pounders per capita, as the collections determination for 2020. This determination involved generating nine different calculated values from various statistical models and calculations based on percent changes from prior years. Figure 1 displays the nine 2020 collections determination values along with the actual collections for 2009-2018 and the 2019 collections determination. The analyses are described in the remainder of this document.

Figure 1: Total Collections and 2020 Collection Determination Predictions



Calculations for 2020 Collections Determination

Nine different 2020 collections determination values were calculated. They include the 2013-2018 method; a modification of the 2013-2018 method; four modeling approaches introduced as part of the 2019 collections determination; and a modeling approach, added this year. A general description for each technique is provided below. Overall, the different techniques are divided into two main groups: (1) calculations based on the sum total of collection weights for all devices, and (2) calculations based on collection weights as split into two groups, according to when collections for the devices were required by law. The first three techniques, which are the 2013-2018 method; the modified 2013-2018 method; and the autoregressive integrated moving average statistical time series, or ARIMA, model, are based on total collection weight for all devices. The remaining techniques split the collection weights. For a more detailed explanation about the techniques, you can contact the Oregon E-Cycles program at info.ecycle@deq.state.or.us.

2013-2018 Method

From 2013 to 2018, DEQ used the same method for calculating the annual collections determination. This method uses collection weights and population data from multiple states to determine the percent change in average per capita collection weights from one year to the next. The calculated percent change is used to calculate a per capita weight for the coming year. The per capita amount is then multiplied by projected population to get the total pounds to be collected in the coming year. Finally, DEQ adjusts that amount to reflect other factors expected to influence collections, as discussed below.

Recent years used the change in average pounds per capita from only two states, Oregon and Washington, which have similar programs. Table 2 displays the pounds per capita and percent change from the prior year for both Oregon and Washington as well as the averages of both states (OR/WA) for each year through 2018.

Table 2: Pounds per Capita and Percent Change by Cohort

Year	Oregon		Washington		OR/WA	
	Pounds per Capita	Percent Change from Prior Year	Pounds per Capita	Percent Change from Prior Year	Average Pounds per Capita	Average Percent Change from Prior Year
2009	5.00		5.78		5.39	
2010	6.30	26.16%	5.87	1.47%	6.09	13.81%
2011	6.71	6.45%	6.18	5.25%	6.44	5.85%
2012	6.89	2.65%	6.30	2.03%	6.60	2.34%
2013	7.06	2.44%	6.48	2.82%	6.77	2.63%
2014	6.91	-2.04%	6.28	-3.07%	6.60	-2.55%
2015*	7.31	5.76%	5.94	-5.46%	6.62	0.15%
2016#	6.43	-11.99%	5.13	-13.67%	5.78	-12.83%
2017	5.82	-9.58%	4.23	-17.56%	5.02	-13.57%
2018	4.82	-17.20%	3.41	-19.31%	4.11	-18.26%

**First year for collections of printers and computer peripherals (keyboards and mice*
#First year using the Oregon Office of Economic Analysis (OEA) and Washington Office of Financial Management (OFM) population estimates for each state respectively instead of the U.S. Census Bureau

To perform the 2013-2018 method, the first step is to determine the average percent change in per capita collection weights for OR/WA from 2017 to 2018 (Table 2) and then apply the percent change to the most recent pounds per capita determination -- 4.05 for 2019 (Table 1) -- to get the pounds per capita estimate for 2020 (Table 3). That pounds per capita estimate multiplied by the projected population[2] for Oregon in 2020 provides the total pounds to be collected for 2020 (Table 3).

Table 3: 2020 Collections Determination (2013-2018 method)

2019 Collections Determination		2020 Collections Determination (2019 lbs. per capita x OR/WA 2018 Avg. % Change)	
Pounds per Capita	Total Pounds	Pounds per Capita	Total Pounds
4.05	17,250,000	3.31	14,235,798

Modified 2013-2018 Method

In the 2013-2018 method, DEQ calculated the 2019 pounds per capita estimate in the spring of 2018 using 2017 collections data. In the modified 2013-2018 method, as shown in Table 4, DEQ

[2] The Oregon Office of Economic Analysis (OEA) demographic forecast for 2019 is 4,300,000.

first recalculates the pounds per capita value for 2019 using more recent collection weights. To do this, DEQ applied the 2018 percent change values for OR, WA, and the OR/WA average to the *actual* Oregon pounds per capita collected in 2018 to get new Oregon pounds per capita estimates for 2019 for each percent change value. The modified method then applies the 2018 percent change values to the new 2019 pounds per capita estimates to arrive at 2020 pounds per capita estimates. As in the 2013-2018 method, the pounds per capita estimates multiplied by the projected population[2] for Oregon in 2020 provides the total pounds to be collected in 2020. The modified method simply updates the 2019 per capita amount based on 2018 collections before determining the 2020 pounds per capita.

Table 4: Alternative Pounds per Capita Method

	OR 2018 Percent Change (-17.20%)		WA 2018 Percent Change (-19.31%)		OR/WA 2018 Average Percent Change (-18.26%)	
	Pounds per Capita	Total Collections	Pounds per Capita	Total Collections	Pounds per Capita	Total Collections
2019 Oregon Estimate	3.99	17,003,739	3.89	16,569,646	3.94	16,786,693
2020 Oregon Estimate	3.30	14,200,533	3.14	13,484,729	3.22	13,840,317

Modeling Approaches

DEQ also used five modeling approaches. Four were introduced for the 2019 collections determination. An additional modeling approach was introduced this year; this approach is a variation to the 2º polynomial model performed in 2019. The variation, All years 2º Polynomial Model + PP, involves using all collection years instead of from 2013 and later. Another change from 2019 is the use of four models to estimate the collection weight for printers and peripherals instead of just one.

The ARIMA model uses the collection weight for all devices added together. The remaining four approaches split the collection weights into two groups: (1) the weights for printers and peripherals and (2) the weights for televisions, computers, and monitors. The selected collection weight for printers and peripherals was then added to each collection weight from the televisions, monitors, and computers models to get a total collections determination value for each model. The collections determination values for each approach are displayed in Table 5. All modeling approaches used actual pounds collected, not pounds per capita.

Table 5: 2020 Alternative Collections Determinations

Alternative Approach	Total Projected Pounds	Percent Change from 2018 Actual Collections	Percent Change from 2019 Determination
ARIMA Model	21,083,344	4.33	22.22
ARIMA + PP	17,676,819	-12.53	2.47
Linear Model + PP	16,997,674	-15.99	-1.58
Post-2013 2º Polynomial Model + PP	10,865,243	-46.23	-37.01
All years 2º Polynomial Model + PP	9,015,122	-55.39	-47.74

ARIMA model

The first model analyzed quarterly collection weights incorporating quarter-to-quarter influences and seasonal trends in collections. Known as the autoregressive integrated moving average statistical time series (ARIMA) model, this model accounts for relationships that sometimes exists between data points that are close in time to each other. Depending on the type of data collected, an association or influence can exist between an earlier and later time point whereby the earlier time point could increase or decrease the value at a later time point. For the Oregon E-Cycles quarterly collection data, two such correlations existed. One was between the weights collected from quarter to quarter. The other was a seasonal trend within a year, where quarters one and four tended to be the lowest. After analyzing the quarterly collection data, the ARIMA model was used to predict each quarter's collections in 2020. The quarters were then totaled to determine the annual collection weight for 2020 (Table 5).

Split models

For the other four modeling approaches, DEQ first evaluated the potential impact of adding the collection of printers and computer peripherals (keyboards and mice) in 2015. In 2015, the total weight of all devices collected was higher than previous years. Further analysis, however, showed that the increased weight resulted from the introduction of two new device types to the E-Cycles program in 2015: printers and peripherals. The added annual weight from these new devices masked a decline in the combined annual weight of televisions, computers and monitors. When the annual weights for each device type are compared separately (Appendix A), it can be seen that the combined annual collection weights for televisions, computers, and monitors have been peaked at 27,731,429 pounds in 2013 and have been declining since. When printers and peripherals were added to the program in 2015, the annual collection weight for all device types combined peaked at 29,420,149 pounds; however, the combined weight in 2015 for televisions, computers, and monitors -- 26,318,800 pounds -- was less than their combined weight in 2013. Since the addition of printers and peripherals is hiding a decrease in collections weights of televisions, monitors, and computers, for the other remaining models, the weights were split into two groups: (1) the sum of the weights for printers and peripherals and (2) the sum of the weights for televisions, computers, and monitors. The selected collection weight for printers and peripherals was then added to each collection weight from the televisions, monitors, and computers models to get a total collections determination value for each model.

Estimating Collection Weight for Printers and Peripherals

To estimate the collection weight for printers and peripherals, four models were used: ARIMA, ETS (error, trend, seasonal exponential smoothing), linear regression, and 2º polynomial. The collection weights from each model for printers and peripherals are displayed in Table 6. ETS was selected as the best model for estimating the collection weight for printers and peripherals because analysis did not indicate a strong correlation between years, which is important for ARIMA models. ETS accounts for the similarity between years by predicting future values as a weighted average of past observations, with the older observations having less of an influence on the average than more recent observations. The selected 2020 collection weight for printers and peripherals (PP) is 3,356,215 pounds.

Table 6: 2020 Collection Weights for Printers and Peripherals

Approach	Total Projected Pounds
ARIMA	3,355,927
ETS	3,356,215
Linear	3,369,418
2º Polynomial	999,529

ARIMA + PP

The first split modeling approach combined an ARIMA model for televisions, computers, and monitors with an ETS-based model for the printer and peripheral collection weight. The 2020 prediction values for this approach are displayed in Table 5.

Linear + PP

This modeling approach used only the annual collection weights for televisions, computers, and monitors from 2013 and later. As mentioned earlier, 2013 was the year when the combined annual collection weights for those devices began declining. The data was restricted to 2013 and later years, because, unlike the ARIMA model, which can adjust to fluctuations (both up and down) in data, the linear model is able to analyze data only unidirectionally (i.e., either up or down). To determine the 2020 collection weight for televisions, computers, and monitors, the linear model fits a straight line through the annual collection weights and projects the rate forward to 2020. Like with the other split approaches, the value from the linear model was combined with the printer and peripheral 2020 collection weight, and is displayed in Table 5.

2º Polynomial Models + PP

Two variations of a 2º polynomial function were performed. One variation analyzed the annual collection weights for televisions, computers and monitors for all years of collection associated with the program (2009-2018). The other variation used the combined annual data for televisions, computers and monitors only from 2013 and later, 2013 being the year when the combined annual collection weights for those devices began declining. The data was reduced for the second variation because of the equation used to fit a curve for 2º polynomials. Unlike the ARIMA model, which can adjust to fluctuations (both up and down) in data, a 2º polynomial model fits a fixed curvilinear shape, specifically an upside down U to this data. In fitting the curvilinear shape, 2º polynomials create a shape that is symmetrical. As it applies to the annual collections for televisions, computers, and monitors, the model would create a declining rate after 2013 that mirrors the rate at which collections increased for those devices from 2009 – 2013. However, as the factors influencing early program collections are likely different from the factors influencing current collection amounts, a symmetrical fit may not be the best approach. Therefore, a reduction in the data to only the time periods since a decline in collections amounts began (i.e. 2013 and later for televisions, computers, and monitors) would allow the 2º polynomial equation to fit a slightly different curve for the reduced number of years compared to the curve using all collection years. By reducing the data, the fit would not be able to mirror the rate of increase in collections prior to 2013 because that information would not exist for the model to use. The 2020 prediction values for both 2º polynomial models were each respectively added to the 2020 collection weight for printers and peripherals. The results are displayed in Table 5.

Other factors considered

Several factors could influence annual collection amounts. The factors include changes in product design, changes in number and type of devices in households, changes in product lifespan, awareness of electronic recycling programs, and storage of obsolete devices.

One well-known product design change is reduced weight, also known as lightweighting. For the same screen size, manufacturers today are able to produce televisions and monitors that are much lighter in weight than models of previous generations. Factors like product lightweighting and declines in household ownership for a specific device would likely result in a decline in annual collection weights. These factors may be counterbalanced by a rebound effect, as product lightweighting may motivate consumers to purchase devices with larger screen sizes. A rebound effect may not be seen in annual collections if the weight of the older devices being disposed are much heavier than the weight of devices being developed and the older devices are being disposed of at a different rate than the newer devices. In 2018, as part of the sampling methodology, the Oregon E-Cycles program began differentiating between cathode ray tube and flat screen televisions as well as CRT and flat screen monitors. According to the analysis (see Table 7), CRT televisions and monitors are about 20 pounds heavier on average than flat screen televisions and monitors. Unlike for monitors, CRT televisions still make up a majority of the televisions returned to the program. While the E-Cycles program's collection weights have declined, it is possible that declines due to lightweighting have been offset partially by a rebound effect, but any effect is likely obscured by the weight of CRT televisions.

Table 7: 2018 Average Weights and Percentages for CRT vs. Flat Screen

	Televisions		Monitors	
	Average Weight (pounds)	Percent of Televisions Sampled	Average Weight (pounds)	Percent of Monitors Sampled
CRT	61	65%	34	19%
Flat Screen	46	35%	11	81%

Another factor considered is that collection weights during the first years of the E-Cycles program likely reflect recycling of stockpiles of obsolete devices in consumer residences. As the stockpiles decline, annual collection weights would also likely decline. Assuming no other changes in the factors mentioned above, as consumer awareness of the E-cycles program reaches saturation, annual collection weights will likely stabilize. While many of the factors mentioned are known to exist, the impacts have not been well studied.

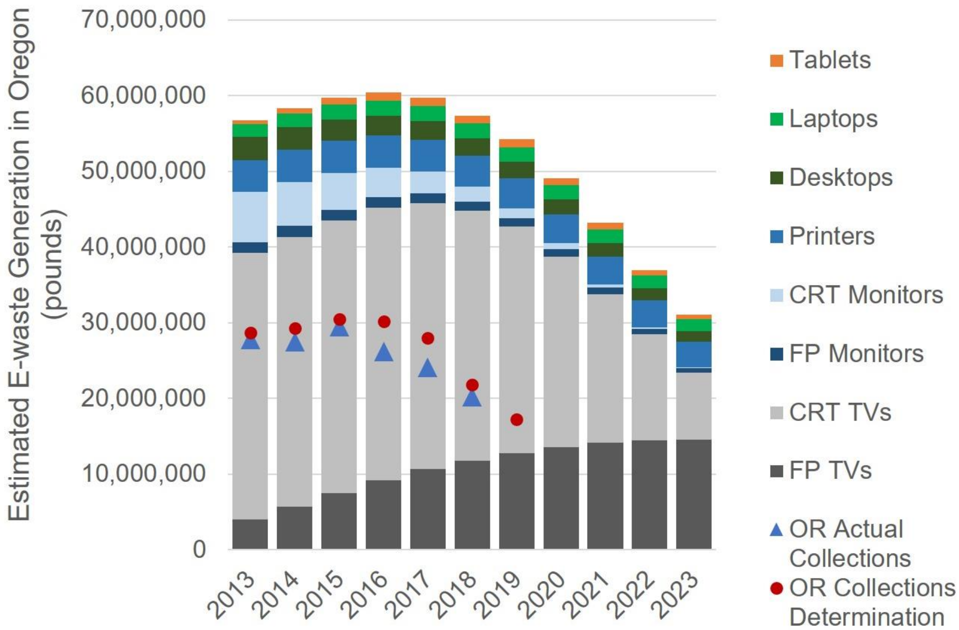
Dr. Babbitt with the Rochester Institute of Technology - Golisano Institute for Sustainability recently developed a predictive model to estimate the future impact of emerging electronic technologies on a variety of sustainability issues, including disposal[3]. In this approach, market sales data for households is used instead of annual returns of electronic devices. The market sales data is also paired with annual estimates for device weights to generate an estimate for the total weight of devices sold. To estimate future disposal of electronic devices, the model combines a logistic growth curve (for estimating product purchases by consumers) with a Weibull distribution (for estimating product lifespan). These combined models are used to estimate future disposal for each product independently based on summing multiple possible estimates of when disposal could occur. The independent product estimates are then combined to get a total estimate for all electronic disposal.

The logistic growth curve was used because of its ability to model the rate at which new devices types are adopted by consumers. For example, when flat panel TVs became available, the price was high; as the price dropped, more people began purchasing the device. Gradually, most of the market transitioned to use of flat panel TVs, with a small minority of people purchasing the flat panel TVs at a much later time compared to their peers. This leads to a model that represents a small number of early adopters and a small number of late adopters with the vast majority of

[3] Babbitt CW, Althaf S, Ryen E, Chen R. 2018. Predictive Modeling of Emerging Technology Products. Staples Sustainable Innovation Lab, RIT- Golisano Institute for Sustainability. Viewed online 3/15/2019. (https://www.rit.edu/gis/ssil/docs/CTA-SSIL%20Final%20Report%20SMM%20Phase%202%202018.pdf)

people being somewhere in the middle. The Weibull distribution was used, because existing literature and data indicated that it was the best probability method for incorporating a wide variety of consumer behaviors related to lifespan, such as use, storage, and disposal. The pattern for the Weibull distribution used in this analysis is similar to a bell-shaped distribution, but the properties of the equation allow it to take on more variations in the shape. The combined approach is able to incorporate several of the factors described in this section such as product lightweighting, product lifespan, and consumer behaviors. At the request of DEQ, Dr. Babbitt's group adapted the model to predict future returns in Oregon. The results of the analysis are displayed in Figure 2.

Figure 2: Total pounds of Electronic Devices potentially available for disposal in Oregon



As with DEQ methods, this analysis suggests that overall collection weights should be declining. However, Dr. Babbitt's model estimates that there are about twice as many pounds available for collection in Oregon than is currently collected by the E-Cycles program. Several reasons could explain the difference. First, the approach estimates the weight of devices that could be disposed; it does not differentiate between reuse and recycling. By comparison, reported collection weights for the E-Cycles program include only recycling. Second, the E-Cycles program is not the only option available for recycling of electronic devices in Oregon. Both of these factors could explain why the E-Cycles is not capturing all of the potential devices available for collection. Other factors that could explain the higher estimate for available collection volume include model assumptions. For example, the model estimates product lifespan; actual product lifespan could be longer than estimated. Similarly, the model used an average estimated weight for each device type, and actual weights could be less. Further work would need to be conducted to validate these assumptions. Overall, the model provides an additional view on possible future collections trends in Oregon and highlights the need to ensure a high level of awareness about the E-Cycles program among Oregonians.

Summary and Explanation for Proposed Amount

Annual collections for the Oregon E-Cycles program have been declining since 2015. Those declines continued in 2018. National trends also show a similar decline[4]. In future years, as the percentage of CRT televisions being returned to the program decreases, the program expects the weight of collections to stop declining at such a fast rate and stabilize, possibly even showing a slight rebound in collection weights.

All 2020 collections determination values are displayed in Figure 1 along with the actual collections for 2009-2018 and the 2019 collections determination. Statistical methods were utilized partly because historical collections are influenced by each of the factors described earlier. While the exact influence of the factors is often unknown, statistical approaches are able to take into account the potential individual influence (i.e. variation) of each factor on the data without knowing the actual influence of any factor.

Collections Determination for 2020

DEQ is proposing 3.20 pounds per capita for total collections of 13,750,000 pounds for the 2020 annual collections determination. This is slightly lower than the 2013-2018 method, but still higher than both 2º polynomial models. DEQ believes this is a conservative, yet realistic value because the majority of the predictions do not indicate the declines in collections to be as severe as predicted by the polynomial models, but do appear to be around a linear decline and is making this proposal with the expectation that the Oregon E-Cycles recycling programs will continue efforts to increase public awareness of collection opportunities especially since the work conducted by Dr. Babbitt's group indicates that more pounds are potentially available to be collected by the programs.

During 2020, DEQ plans to continue to review methods for determining the collections for 2021 and beyond with interested people, and more broadly, to work with them in evaluating and updating Oregon E-Cycles as the world of electronics changes.

Alternative formats

DEQ can provide documents in an alternate format or in a language other than English upon request. Call DEQ at 800-452-4011 or email deqinfo@deq.state.or.us.

[4] Babbitt CW, Althaf S, Chen R. 2017. Development of a Sustainable Materials Management Modeling Framework and Baseline Model Results. Staples Sustainable Innovation Lab, RIT- Golisano Institute for Sustainability. Viewed online 3/15/2019. (https://www.rit.edu/gis/ssil/docs/Final%20Report%20SMM%20Phase%201%202017.pdf)

Appendix A

Oregon Actual Collections (in pounds) by Device Type					
Year	**Televisions**	**Computers**	**Monitors**	**Printers**	**Peripherals**
2009	10,884,263	2,044,426	6,187,101	N/A	N/A
2010	14,889,227	2,784,099	6,477,022	N/A	N/A
2011	17,975,999	2,138,987	5,770,963	N/A	N/A
2012	20,173,234	1,904,405	4,592,802	N/A	N/A
2013	21,690,705	2,209,591	3,831,133	N/A	N/A
2014	21,885,680	2,364,333	3,179,926	N/A	N/A
2015*	21,149,446	2,370,537	2,798,817	2,828,513	272,837
2016	18,044,919	2,333,860	2,177,483	3,241,119	428,379
2017	16,421,936	2,291,518	1,903,424	3,157,116	316,128
2018	13,407,548	2,068,177	1,552,687	2,876,214	303,402

**First year for collections of printers and computer peripherals (keyboards and mice)*