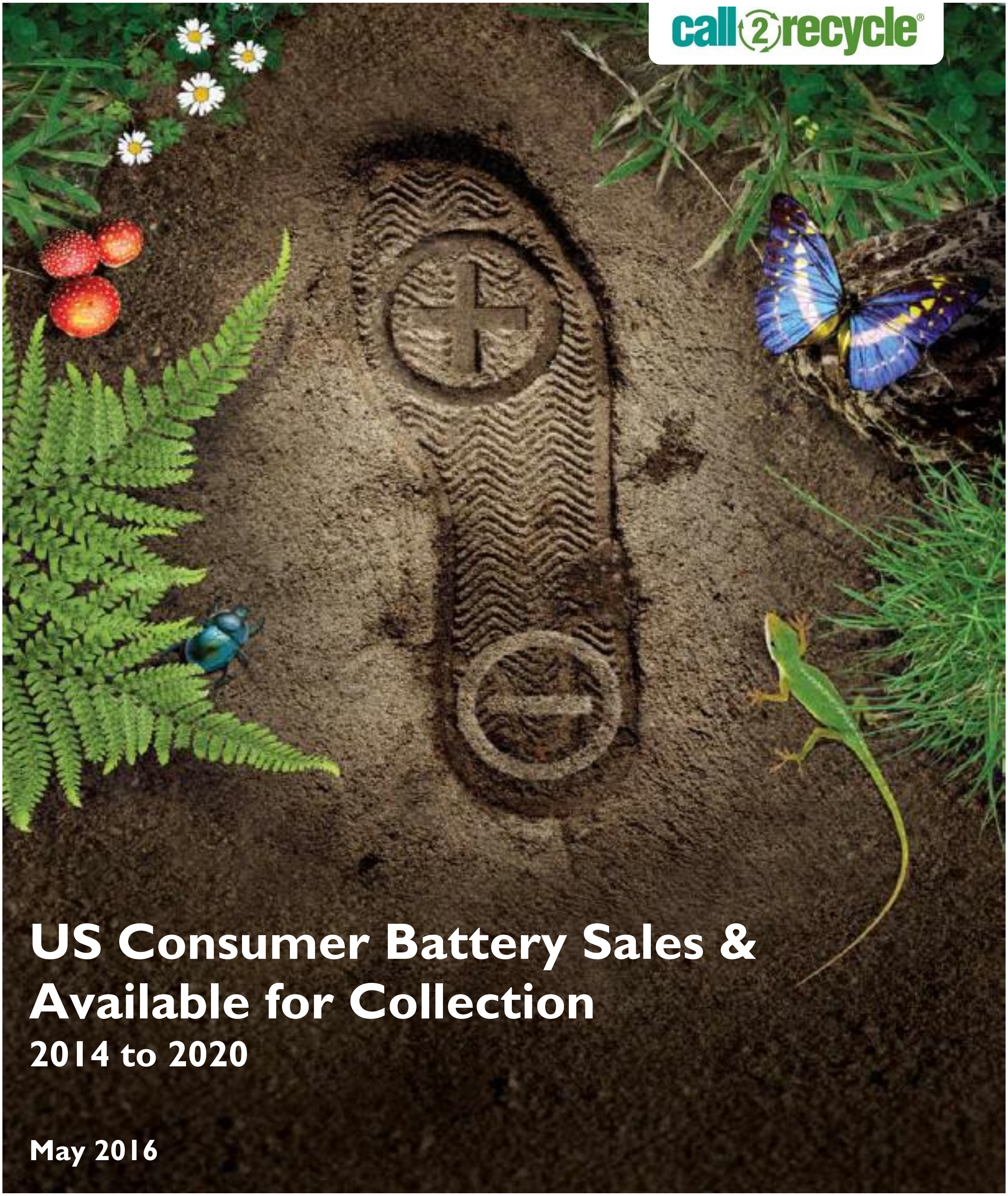


US Consumer Battery Sales & Available for Collection

2014 to 2020

May 2016

A report commissioned by Call2Recycle, Inc.

Prepared by Kelleher Environmental in association with SAMI Environmental

Introduction

Determining sales of consumer batteries into any given market is elusive. Batteries are sold through many channels and are often integrated into the products they power. Even the precise definition of a "battery" is often subject to varying interpretations. This complicates calculating several metrics, most particularly determining whether a consumer battery collection and recycling program is performing well.

Further complicating such measures is determining what portion of sales is truly recoverable for collection and recycling. Some clearly are and others – like batteries that are wholly embedded into the products they power – are likely not.

Call2Recycle, Inc., the North American leader in collecting and recycling consumer batteries, hired environmental consulting firm, Kelleher Environmental to examine these issues. While there have been several attempts to assess to what extent batteries are available for collection, many of which will be cited in this report, we felt that further work was necessary to better analyze battery sales. This report significantly adds to that discussion.

Specifically, the topics covered within the report provide insights into:

A. The estimated number and weight of consumer batteries sold into the US market.
B. How long batteries remain in market (Lifecycle impact).
C. The impact that batteries embedded into products play in the evolution of battery recycling.
D. The estimated weight of batteries that are available to be collected and, ultimately recycled.

Generally, the conclusion of the report is that batteries available for collection must be calculated by first taking sales into any given marketplace, adjusted for the lifecycle of the battery, minus those batteries embedded in products that are unlikely to ever be recycled separately.

Call2Recycle, Inc., would like to thank Maria Kelleher and her team for the exceptional work on this issue. No one understands the complexities of calculating product sales better than Maria and her patience and stamina in dealing with battery sales has no equal.

Call2Recycle would also like to thank Dr. Mathew Realff from the Georgia Institute of Technology for providing his insight through an extensive peer review of this report.

Call2Recycle, Inc.
May 2016

A. Estimating Consumer Battery Sales

Estimates for both primary and rechargeable dry cell batteries sold into the United States (US) have been developed through 2020. Only those primary and rechargeable batteries that are intended for use in consumer products were included, while other wet and dry cell batteries intended for use usage in automotive, industrial, or large format power supply have been excluded.

Table 1: Primary and Rechargeable Consumer Batteries Addressed in the Call2Recycle Study

Primary Consumer Battery Chemistries	Rechargeable Consumer Battery Chemistries
Alkaline	Lithium Ion (Li-Ion)
Zinc Carbon	Nickel Metal Hydride (Ni-MH)
Lithium Primary (metal)	Nickel Cadmium (Ni-Cd)
Other Primary	Small Sealed Lead Acid (SSLA/Pb)

Estimates for primary consumer battery sales were derived using multiple sources of data including The Nielsen Corporation, battery manufacturers, and web-based research. The Nielsen Corporation provided syndicated data for batteries sold through major retail chains within the US. Knowing Nielsen data only represents batteries sold through the retail channel, total primary consumer battery sales were grossed up to account for primary batteries sold through other channels such as: industrial, medical, and direct to original equipment manufacturers (OEMs) for use in products such as toys, flashlights, remote controls, and other consumer devices. Total battery weight sold into the market was estimated by multiplying the number of units of each primary battery chemistry and type sold by average unit weights that were determined through web-based research.

Estimates for secondary consumer batteries were developed based on information contained in a number of sources, including: Nielsen syndicated data; a 2015 report by the Consumer Electronics Association (CEA)[1]; a report on Power and Hand Tools[2] by The Freedonia Group Inc. (Freedonia); a report on batteries by Freedonia (November, 2013)[3], a report prepared by Battery Council International (BCI) on recycling of small sealed lead acid (SSLA) batteries[4] and reports produced by battery stewardship-related research organizations in Europe and Australia. In addition, extensive web-based research was undertaken.

Projections for primary consumer battery sales to 2020 were based on a combination of Nielsen and Freedonia data.

Projections of secondary consumer battery sales to 2020 were developed from information provided in the Freedonia Battery report (2013)[3], as well as BCI data.

[1] Consumer Electronics Association (CEA). July 2015. *US Consumer Electronics Sales and Forecasts, 2011 to 2016*
[2] Power and Hand Tools (2014) available at: www.freedoniagroup.com/Power-And-Hand-Tools.html
[3] The Freedonia Group Inc.: Industry Study #3075 Batteries, November, 2013
[4] Battery Council International (BCI). National Recycling Rate Study. Prepared by Smith, Bucklin and Associates, Inc. April 2014

Utilizing the methodology and sources described above, Call2Recycle estimates nearly 6.7 billion batteries were sold into US markets in 2014, weighing 242.7 million kilograms.

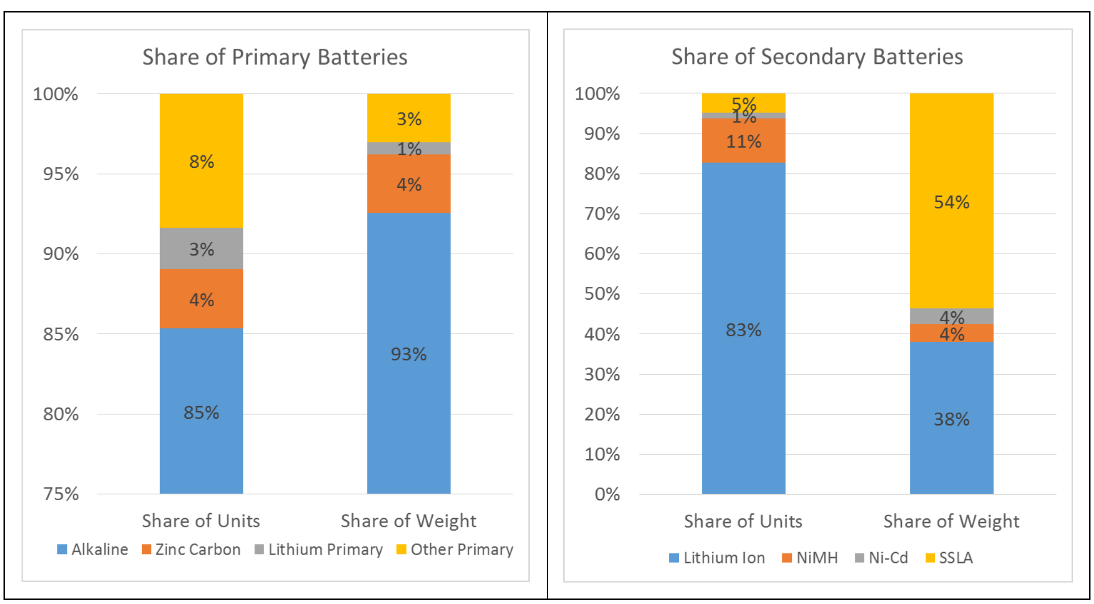
Table 2: Estimated Primary and Secondary Consumer Batteries Sold in the US in 2014 (Units and Weight)

Battery Chemistry	Units Sold (thousands)	Share of Units	Weight Sold (kg)	Share of Weight
Alkaline	5,408,167	79.7%	150,796,174	62.1%
Zinc Carbon	234,330	3.5%	5,949,243	2.5%
Lithium Primary	165,345	2.4%	1,231,048	0.5%
Other Primary	529,980	7.8%	4,918,649	2.0%
Li-Ion	367,223	5.4%	30,305,606	12.5%
Ni-MH	49,247	0.7%	3,557,250	1.5%
Ni-Cd	6,150	0.1%	3,099,950	1.3%
SSLA/Pb	21,420	0.3%	42,839,482	17.7%
Total Primary	6,337,822	93.5%	162,895,114	67.1%
Total Rechargeable	444,040	6.5%	79,802,288	32.9%
Total Battery	6,781,862	100.0%	242,697,402	100.0%

As shown in Table 2, over 90% of batteries marketed in the US by weight are from alkaline, SSLA/Pb, and Li-Ion chemistries. In 2014 alkaline batteries represented over 60% of battery weight sold, while SSLA/Pb and Li-Ion are estimated to be 18% and 12% respectively.

The relative share that each battery chemistry represents within its respective category varies considerably when making unit and weight volume based comparisons, especially in the case of rechargeable batteries. For example, over 80% of rechargeable battery units marketed in 2014 were classified as Li-Ion, while less than 40% were marketed by weight. SSLA/Pb batteries are a relatively small player in terms of rechargeable battery units sold at near 5%, but represent the largest share (54%) by weight, given the heavier nature of these batteries.

Figure 1: Estimated unit and volume share of primary and secondary batteries



The share of US batteries in comparison to other jurisdictions around the world vary widely. Table 3 displays battery share for a handful of jurisdictions. Of those jurisdictions listed, the US and German markets most closely resemble each other for most battery types, with the exception of SSLA/Pb and Ni-MH.

Table 3: Proportion of Different Consumer Battery Chemistries in Selected Markets (kgs)

Chemistry	Australia	Germany % by weight	Selected EU[5] (2012)	US
Alkaline	28.6%	65.8%	44.2%	62.1%
Zinc carbon	20.0%	5.7%	10.0%	2.5%
Lithium primary	0.7%	2.0%	1.6%	0.5%
Li-Ion	23.6%	15.3%	16.6%	12.5%
Ni-MH	1.0%	6.8%	6.0%	1.5%
Ni-Cd	1.5%	1.2%	4.9%	1.3%
SSLA/Pb	24.4%	2.5%	16.6%	17.7%

Over the next 5 years, the battery category is poised to change substantially in sales and mix. The volume of single-use batteries sold into the US is expected to decline by over 8 million kgs, while rechargeable batteries are anticipated to increase by over 13 million kilograms. In 2014, the estimated split of battery sales by weight was 67% primary and 33% rechargeable. This is expected to shift closer to a 60%/40% split respectively by the end of the decade.

Li-Ion is expected to grow an average of over 5% per year from an estimated 30.3 million kgs to over 42 million kgs by 2020. Ni-Cd is expected to decline an average of 4.5% per year with just over 2 million kgs placed on the market by 2020. Refer to Table 4 additional details.

Table 4: Battery Sales Estimates through 2020 (kgs) in the USA

Chemistry	2014	2020	Compound Growth Rate
Alkaline	150,796,174	143,788,108	-0.8%
Zinc Carbon	5,949,243	5,064,589	-2.6%
Lithium Primary	1,231,048	1,266,989	0.5%
Other Primary	4,918,649	4,504,360	-1.5%
Lithium Ion	30,305,606	42,091,323	5.6%
Ni-MH	3,557,250	3,744,669	0.9%
Ni-Cd	3,099,950	2,345,600	-4.5%
SSLA/Pb	42,839,482	45,045,889	0.8%
Total Primary	162,895,114	154,624,046	-0.9%
Total Rechargeable	79,802,288	93,227,481	2.6%
Total Battery	242,697,402	247,851,527	0.4%
% Primary	67.1%	62.4%	
% Secondary	32.9%	37.6%	

[5] Eurobat membership from 12 EU Countries

B. Lifecycle Impact

The length of time between the purchase of a consumer battery and when it is available to recycle is a combination of the active life of the battery, the ability to remove the battery from the device, and any period of time when the battery is stored or "hoarded". Various approaches are used to estimate the total time between purchasing and discarding to take account of the different phases in the lifespan of a battery.

A number of sources of consumer battery lifespan data (the number of years after a consumer battery enters the market when it becomes available to recycle) were reviewed for the report. It is recognized that battery lifespan age distributions are likely to change over time as some products and battery chemistries leave the market and new products and new battery chemistries enter the market. The most comprehensive of these sources is a recent study conducted by Bebat (battery collection scheme in Belgium) in 2014, where approximately 30,000 batteries of different chemistries were sampled at recycling facilities (total of 3,900 kg from 850 manufacturers).[6] This information is considered "best in class" information available at this time on consumer battery lifespan distributions, and was therefore used in the Lifespan Model, recognizing that the distributions may change over time, and that consumer behavior may be different in Belgium than in the USA. However, the Bebat research results provide the best snapshot of the age distribution of different battery chemistries dropped off at their program. The Bebat data were adjusted to reflect an average lifespan reported by Battery Council International (BCI)[7] for SSLA/Pb batteries.

Table 5 shows the cumulative age distribution of consumer batteries measured in the Bebat study. Primary batteries have a much shorter lifespan than rechargeable batteries, with approximately 80% of alkaline batteries disposed of by year 7. Li-Ion and Ni-Cd batteries don't reach 80% disposal rate until year 11 and year 15+ respectively. Given this information, varying methodologies should be considered when calculating recycling rates for primary and rechargeable chemistries.

Table 5: Cumulative Age Distribution of Consumer Batteries for Lifespan Model (Cumulative % Reaching End of Life vs Year of Purchase)

Year After Purchase when battery reaches end of life	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Alkaline	2.9%	10.7%	28.8%	42.7%	61.3%	72.9%	81.9%	84.9%	87.4%	90.3%	93.0%	95.3%	96.8%	98.1%	99.1%
Zinc Carbon	1.2%	11.2%	22.3%	35.1%	47.8%	58.4%	68.6%	77.7%	83.7%	87.4%	91.2%	92.9%	94.4%	95.6%	95.9%
Lithium Primary	1.9%	27.5%	42.9%	52.5%	60.9%	66.1%	70.0%	77.4%	80.1%	80.9%	82.3%	83.5%	84.7%	85.2%	96.3%
Li-Ion	1.0%	7.7%	15.7%	25.1%	33.5%	42.2%	56.1%	62.9%	70.1%	75.9%	79.8%	84.8%	87.0%	93.7%	95.2%
Ni-MH	16.7%	29.3%	43.4%	51.2%	59.2%	69.2%	77.4%	88.6%	91.8%	95.4%	96.6%	98.1%	98.3%	99.2%	99.3%
Ni-Cd	5.4%	22.1%	31.3%	36.6%	38.9%	41.7%	43.7%	57.3%	59.1%	61.0%	61.5%	65.1%	68.5%	72.7%	75.3%
SSLA/PB	3.0%	5.0%	13.0%	49.0%	69.0%	87.3%	93.3%	96.3%	See Footnote						

Footnote: Remaining percentage distributed evenly between 16 and 20 year lifespan. Lifespan adjusted to reconcile with average lifespan quoted by BCI for SSLA/PB batteries.

To estimate the amount of batteries available for recycling using lifespan modeling, it is critical to have an understanding of historical sales rates of batteries, as well as the ability to remove the battery from the product. Sales data for primary batteries for five years (2010 to 2014) were obtained from Nielsen

[6] BEBAT. 24/09/2014. "How the battery life cycle influences the collection rate of battery collection schemes. PowerPoint Presentation at ICBR Hamburg. Prof. dr. Bram Desmet, Anne-Sophie Mertens Mobius. Peter Coonen, Bebat.

[7] Battery Council International. April, 2014. National Recycling Rate Study. Prepared by SmithBucklin Statistics Group, Chicago, Illinois.

for the US. Values for 2002 to 2009 were estimated using compound annual growth rate (CAGR) data from the Freedonia Battery Report (2013)[8].

For rechargeable batteries, historical sales of Li-Ion and Ni-MH consumer batteries from 2002 to 2013 were developed using detailed 2014 sales estimates from this report and applying CAGR values for 2002 to 2013 from the Freedonia Battery Report (2013)[9]. Historical sales of SSLA/Pb batteries were developed using data from BCI. Historical sales for Ni-Cd batteries were developed using data from the Environment Canada Battery Study (2009)[10], and assuming a constant CAGR decline between 2002 and 2014, to reflect the significant decline in Ni-Cd battery sales as Li-Ion batteries increased in popularity for many applications which used Ni-Cd batteries.

The results of the available to recycle analysis for 2014 and 2020 are presented in Table 6 for the US. The results show that alkaline batteries are estimated to still be the predominant consumer battery reaching end of life in the US in 2014. Relatively more rechargeable batteries are projected to become available for recycling in future years. It is important to note that those batteries sold embedded in other products, whether easily removable or not by the consumer, are captured in these numbers.

Table 6: Estimated Consumer Batteries Adjusted for Lifespan in the US 2014 to 2020 (kg)

Chemistry	2014	2020	% of total in 2014	% of total in 2020
Alkaline	171,413,580	154,414,378	63.1%	60.3%
Zinc Carbon	11,319,585	7,288,244	4.2%	2.8%
Lithium Primary	1,269,023	1,248,332	0.5%	0.5%
Other Primary	6,003,013	5,222,111	2.2%	2.0%
Li-Ion	15,672,974	26,480,128	5.8%	10.3%
Ni-MH	3,236,822	3,586,507	1.2%	1.4%
Ni-Cd	21,087,522	14,563,694	7.8%	5.7%
SSLA/Pb	41,607,905	43,272,117	15.3%	16.9%
Total Primary	190,005,201	168,173,065	70.0%	65.7%
Total Rechargeable	81,605,224	87,902,447	30.0%	34.3%
Total Battery	271,610,424	256,075,512	100%	100%

Table 6 shows that in 2014 primary batteries made up an estimated 70% of the weight of consumer batteries available to recycle in the US, and that secondary batteries made up an estimated 30% of the weight.

By 2020, the weight of secondary batteries available to recycle in the US is projected to increase compared to primary batteries, contributing an estimated 34.3% of the total weight, with primary batteries dropping to an estimated 65.7% of the total weight of consumer batteries available to recycle. This change is mainly a result of an estimated 17 million kg less of alkaline batteries available to recycle, related to a reduced demand for alkaline primary batteries over time.

8 Freedonia Group. November 2013. Industry Study #3075 – Batteries.
9 Ibid
10 Environment Canada and Natural Resources Canada. January, 2009. Battery Recycling in Canada – 2009 Update. Prepared by Kelleher Environmental

C. Embedded Battery Impact

Many consumer products are now sold with enclosed batteries that may or may not be easily removable. While some of these batteries may be removable by the manufacturer, many are now designed in a way that makes it nearly impossible for the consumer to remove. In fact, many non-removable batteries are built into the product (i.e. glued or clipped in), meaning the battery cannot be separated from the device. These encased batteries should be acknowledged and managed through product recovery, rather than individual battery recovery. Given this information, it is challenging to include these batteries into available for collection numbers – as these batteries in many cases are managed through business channels, rather than directly from consumers. Therefore, available for collection calculations are dependent upon consumer access to the given battery.

To provide additional context and impact to recycling rates, Table 7 below estimates the percentage of batteries that were removable in 2014, and recyclable by consumers. The largest impact at this time, is for Li-Ion batteries. The amount of Li-Ion batteries embedded in products through 2020 is expected to increase, mostly from growth in the consumer electronic product category. It should be noted that where no data were available (for all primary and SSLA/Pb batteries) a default value of 1% non-removable was used.

Table 7: Estimated Consumer Batteries Sold into the US Market Which are Removable and Non-Removable in 2014 (kg)

Battery Chemistry	Sold into US Market 2014 (kg)	% Removable – Sold Into Market 2014	% Non-Removable Sold Into Market 2014	Kg Removable – Sold Into Market 2014	Kg Non-Removable Sold Into Market 2014
Alkaline	150,796,174	99%	1%	149,288,212	1,507,962
Zinc Carbon	5,949,243	99%	1%	5,889,751	59,492
Lithium Primary	1,231,048	99%	1%	1,218,738	12,310
Other Primary	4,918,649	99%	1%	4,869,463	49,186
Li-Ion	30,305,606	43%	57%	13,031,411	17,274,195
Ni-MH	3,557,250	58%	42%	2,063,205	1,494,045
Ni-Cd	3,099,950	67%	33%	2,076,967	1,022,984
SSLA/Pb	42,839,482	99%	1%	42,411,087	428,395
Total Primary	162,895,114	99%	1%	161,266,164	1,628,950
Total Rechargeable	79,802,288	75%	25%	59,582,670	20,219,618
Total Battery	242,697,402	91%	9%	220,848,832	21,848,570

D. Available for Collection: Sales (Lifecycle) – Embedded = Available

The amount of batteries available for collection is shown below in Table 8. This is derived by (A) estimating sales into the market in 2014, (B) adjusting the amount of sales in market based on battery lifespan, and (C) subtracting the amount of batteries that are embedded into products over time.

This methodology is more relevant for rechargeable batteries given (1) longer battery and product lifespans and (2) the ever-increasing nature of embedded batteries. For primary batteries, a multiyear sales cycle (3-5) years is justifiable given that close to 60% of the batteries sold have already reached end of life in that time frame.

Table 8: Available for Collection Methodology (kg)

Chemistry	2014 Sales	Historical Sales Adjusted for Lifespan	2014 Embedded Battery Factor	Available to Recycle
Alkaline	150,796,174	171,413,580	1%	169,699,444
Zinc Carbon	5,949,243	11,319,585	1%	11,206,389
Lithium Primary	1,231,048	1,269,023	1%	1,256,333
Other Primary	4,918,649	6,003,013	1%	5,942,983
Li-Ion	30,305,606	15,672,974	57%	12,545,397
Ni-MH	3,557,250	3,236,822	42%	1,877,357
Ni-Cd	3,099,950	21,087,522	33%	14,128,640
SSLA/Pb	42,839,482	41,607,905	1%	41,191,826
Total Primary	162,895,114	190,005,201	1%	188,105,149
Total Rechargeable	79,802,288	81,605,224	25%	69,743,220
Total Battery	242,697,402	271,610,424	9%	257,848,368

With this methodology in place, it is clear to see that rechargeable batteries stay in market long after sales take place (Ni-Cd). Additionally, the amount available to recycle is lower than sales for newer chemistries (Li-Ion), as these batteries have not yet reached their end of life.

Table 9 below provides the estimated amount of batteries available to recycle through 2020. Although Li-Ion batteries are anticipated to grow by over 5% per year through 2020, the amount available to recycle will be relatively flat from 2014, due to the expected increase in the number of batteries being embedded into products in future years. By 2020, almost 10 million kgs of Ni-Cd batteries are expected to be available to recycle, even though sales will be a fraction of what they are today.

Table 9: Estimated Consumer Batteries Available to Recycle in the US 2014 to 2020 Excluding Embedded Batteries (kg)

Chemistry	2014	2020	% of total in 2014	% of total in 2020
Alkaline	169,699,444	152,870,234	65.8%	65.5%
Zinc Carbon	11,206,389	7,215,362	4.3%	3.1%
Lithium Primary	1,256,333	1,235,849	0.5%	0.5%
Other Primary	5,942,983	5,169,890	2.3%	2.2%
Li-Ion	12,545,397	12,080,266	4.9%	5.2%
Ni-MH	1,877,357	2,080,174	0.7%	0.9%
Ni-Cd	14,128,640	9,757,675	5.48%	4.18%
SSLA/Pb	41,191,826	42,839,396	16.0%	18.4%
Total Primary	188,105,149	166,491,334	73.0%	71.4%
Total Rechargeable	69,743,220	66,757,511	27.0%	28.6%
Total Battery	257,848,368	233,248,846	100.0%	100.0%

Conclusion

Estimating sales of consumer batteries into any given market, as well as determining the amount available for collection is complex and elusive. It is imperative to understand this, especially when it comes time to determining whether a consumer battery collection and recycling program is performing well.

As we have learned, the amount of time a given battery stays on the market varies based on the active life of the battery chemistry; the product design and whether or not the consumer can easily remove the battery for replacement; and, the amount of time a battery is stored or "hoarded".

As the battery category continues to evolve, it is clear that determining the amount of consumer primary batteries and secondary batteries available for collection requires differing methodologies.

- Since single-use batteries have a shorter lifecycle and are more likely to be easily removed from a product, using sales into the market as the denominator in calculating collection rates and recycling program performance is a reasonably accurate methodology.
- Contrary to this, rechargeable batteries have a longer lifecycle and, for some chemistries and product applications, more likely to be embedded in a product. Applying a lifecycle model and identifying embedded batteries is the only acceptable approach for determining what is available for collection.