Product Stewardship Institute, Inc.

Battery Performance Metrics: Recommendations for Best Practice

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This report was developed by the Product Stewardship Institute, Inc., under contract with the Rechargeable Battery Recycling Corporation.

The Rechargeable Battery Recycling Corporation

The Rechargeable Battery Recycling Corporation (RBRC) is a non-profit, public service organization created by the rechargeable power industry and dedicated to the recycling of rechargeable batteries. In pursuit of its mission, RBRC also collects old cell phones. RBRC operates in the United States and Canada.

The Product Stewardship Institute

The Product Stewardship Institute (PSI) works to ensure that all those involved in the lifecycle of a product share responsibility for reducing its health and environmental impacts. PSI's members include 45 US states, over 100 local governments, and more than 50 businesses, environmental groups, and organizations.

Battery Performance Metrics:
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Battery Performance Metrics: Recommendations for Best Practice

Significant efforts are underway in North America to collect and recycle spent batteries, yielding thousands of tons of recovered material. But are these efforts effective, and do they meet the expectations of policymakers, manufacturers, and the public? Policymakers need to ensure that environmental risks are being adequately addressed; product manufacturers need to know whether their resources are well-spent; and consumers need to be confident that product stewardship initiatives are reaping environmental benefits. But, as for many products, the performance of battery stewardship efforts is difficult to measure.

This report offers guidance to those wanting to assess the performance of battery collection and recycling programs. It provides an overview of the reasons to measure performance, the characteristics of sound performance metrics, and types of performance indicators. It outlines how battery recycling programs are being evaluated in the United States and internationally and how performance is measured for other product take-back programs. It also offers recommendations for how to measure the performance of battery collection and recycling programs while considering other important measures of sustainability in battery lifecycles.

Why Measure Performance?

For both manufacturers responsible for financing battery collection and recycling programs and policymakers, performance measurement and reporting offer many advantages:[1]

- **Motivate improved performance.** Almost always, improving performance requires an investment of resources: time, money, and attention. Without knowing how well a collection effort is working, public- and private-sector decision-makers have little basis to invest more resources to strengthen programs. Performance measurement is a first step in performance improvement. With knowledge about a program's effectiveness, decision-makers can determine whether to use scarce resources to bolster collection efforts and the urgency and appropriate magnitude of that investment.

- **Facilitate comparison and learning**. A common metric for battery collection and recycling efforts facilitates comparison among battery stewardship programs. By comparing different programs, decision-makers can identify strong and weak efforts and determine those features that make high-performing programs successful. They can replicate those features when starting new programs or attempting to improve lagging efforts.

[1] For further discussion of internal and external benefits of performance reporting, see Stratos. 2007. *Performance Measurement and Reporting for Extended Producer Responsibility Programs.*

- **Demonstrate commitment to program outcomes.** By regularly reporting performance to the public, manufacturers demonstrate their commitment to program results. Similarly, by requiring manufacturers to report their performance, policymakers communicate their commitment to hold manufacturers accountable. Conversely, lack of attention to performance reporting may send the message that those responsible for a program are not concerned about outcomes.

- **Satisfy regulatory requirements.** As a practical matter, many jurisdictions that mandate battery collection and recycling also require annual reporting of performance. Easy-to-use and commonly agreed-upon performance metrics can make such reporting more straightforward.

Manufacturers and policymakers share an interest in performance reporting. They may, however, hold different views about what aspects of performance are most appropriate to track and share. Performance measurement requires the collection of data, which can be time-consuming and costly. If a metric is based on a comparison of products collected to products sold, manufacturers may need to take steps to protect sales information that they consider confidential. Information reported to the public sends a message about program successes and shortcomings that may lead to public demands to bolster collection and recycling efforts. Performance measurement is the yardstick against which policymakers and consumers evaluate manufacturers' product stewardship efforts. It is especially important, therefore, that performance measures are sound.

Characteristics of Sound Performance Metrics

Sound performance metrics share a set of defining characteristics: they are relevant, of high quality, easy to use, transparent and accessible, widely accepted, and adaptable.[2]

- **Relevant**. Sound performance metrics measure attributes of performance that are relevant to a program's goals. If policymakers have called for a battery collection and recycling initiative in order to ensure appropriate end-of-life management of batteries (e.g. preventing metals from contaminating the environment), performance metrics should measure the extent to which those programs capture and contain toxic metals. If, alternatively, policymakers have required a battery collection program to conserve product inputs (e.g. energy and other resources consumed in product manufacture), performance metrics should address resource savings from collection and recycling

[2] Jonathan Borck, Cary Coglianese, and Jennifer Nash. 2008. "Environmental Leadership Programs: Toward an Initial Assessment." 35 *Ecology Law Quarterly* 771.

efforts. Of course, program goals may be multiple, may not be stated explicitly in legislation or elsewhere, and may change over time.

- **High quality.** Sound performance metrics are based on data that are credible and reliable.[3] Credible data are collected in accordance with recognized practices and understandable instructions such that two organizations, charged with the same data-collection task, would come up with the same result. Reliable data are verified, meaning that a third party has made sure that data are complete and accurate.

- **Easy to use.** Performance assessment should not be a laborious exercise. Policymakers need performance metrics that help them quickly and easily determine whether their efforts are on track to meet goals. The costs associated with performance measurement should be proportionate to the costs of the collection and recycling effort overall.

- **Transparent and accessible.** Sound performance metrics are transparent. The assumptions those responsible use to generate them are prominently stated. Often those assumptions are developed through a process of public discussion and debate. Similarly, the sources of data used to develop performance metrics are clearly identified.

- **Widely accepted**. Sound performance metrics are widely accepted. They represent a consensus of the best thinking about how to measure performance.

- **Adaptable**. Performance metrics are not static. As experience in measuring performance grows and more data become available, performance metrics should evolve. While stability enables comparisons over time, adaptability is also important given that measuring the performance of product stewardship efforts is relatively new. We can expect metrics to change as policy makers focus on new aspects of performance (such as the release of greenhouse gases throughout product life cycles), new sources of data become available, new products come to market, and we learn more about consumer behavior and other factors that underlie assumptions.

Types of Performance Indicators

Before considering the different metrics in use today for assessing the performance of battery collection and recycling efforts, it is helpful to consider the different ways that performance *could* be measured. We have identified three categories of performance: program

[3] Ibid., p. 801.

convenience, program results, and program benefits in relationship to costs. In practice, program convenience is probably the most commonly used performance measure, while relatively little attention has been devoted to measuring the relationship between program benefits and costs. In recent years, policymakers have placed increasing emphasis on measuring program results.

- **Program convenience**. Program convenience refers to the way the program is set up and run. Performance indicators include the public's awareness of the program, number and type of collection sites, the proximity of collection points to program users, and costs to participate.

- **Program results**. The second approach measures program results: the number or weight of products collected and recycled. Results can be communicated as absolute numbers or *in comparison to a reference point*. That reference point might be past performance, such as the amount collected at the start of the program or during the previous year. The reference point might be the amount collected by a particularly successful program. It might be the population of an area or size of an area of land. Increasingly, policymakers are referencing the amount available for collection as the most relevant point of comparison. The amount available for collection might be based on amount sold or amount discarded. Table 1 lists reference points used by various collection programs.

- **Program economic, environmental, and social benefits compared to costs**. A third approach measures program benefits in relationship to costs. Conceivably, policymakers could set the goal of collection and recycling *all* material introduced into the market. At some point, however, the lifecycle economic, environmental, and social costs of battery collection and recycling might be greater than the lifecycle economic, environmental, and social costs of disposing of batteries in a landfill or incinerator. The tipping point at which the costs of collection and recycling exceed the benefits is determined by many factors, including the extent of the collection infrastructure, market for recycled materials, the effectiveness of educational efforts, and sources of energy used for transportation and reprocessing. These factors vary over time and from place to place.

Table 1: Reference Points Used in Product Collection and Recycling Metrics

Number or weight of product collected compared to:	• Base year, previous year
	• Amount collected in "best" programs
	• Population in a given geographic region (collections per capita); size of an area of land
	• Amount available for collection based on product sales, amount observed in the waste stream

The appropriate approach to measuring performance depends on many factors, most importantly the goals of the program. If the goal of a product collection and recycling effort is to provide consumers with opportunities to recycle, program convenience is the most appropriate performance category. If the goal of a program is to achieve a given collection or recycling rate,[4] then measuring quantities of material as a percentage of the amount available for collection is most important. Often battery collection programs are not required by law, or the law says nothing about how performance is to be measured or reported. In such cases, stakeholders must decide for themselves how best to measure performance.

Inventory of Battery Collection and Recycling Metrics

What constitutes "best practice" in measuring the performance of battery collection and recycling programs is evolving rapidly. In this section we consider metrics used by the Rechargeable Battery Recycling Corporation (RBRC) and the Battery Council International (BCI), and proposed or in use by governments in the United States, Europe, and Canada.

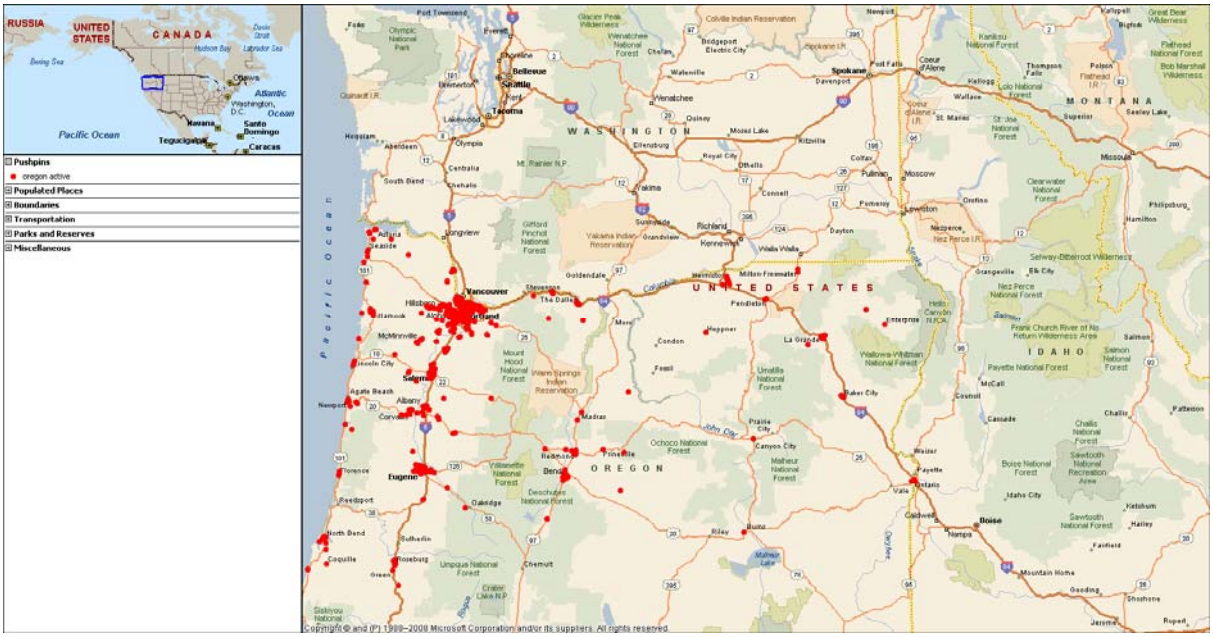
Rechargeable Battery Recycling Corporation (RBRC). Rechargeable battery manufacturers created the RBRC in 1994 to promote recycling of used rechargeable batteries in the United

[4] We define *collection rate* as the actual amount of batteries collected divided by the estimated amount available for collection. Collection rate should be distinguished from recovery rate and recycling rate. *Recovery rate* is the amount of battery material recycled into other products compared to the amount collected. *Recycling rate* is the collection rate multiplied by the recovery rate. For example, if 4 lbs. batteries are collected and 10 lbs. are available for collection, the collection rate is 40% (4 lbs/10 lbs). If 3 lbs of the batteries collected are recycled into other products, the recovery rate is 75% (3 lbs/4 lbs). In this scenario, the recycling rate is 30% (40% * 75%).

States and Canada. RBRC began collecting Nickel-Cadmium (Ni-Cd) batteries in 1994, eventually expanding to collect the other rechargeable models (Lithium-Ion, Nickel-Metal Hydride, Small Sealed Lead-Acid) in 2001. It collects and manages information about many aspects of its performance including the convenience and results of its collection programs.

In terms of convenience, RBRC compiles information on the number and location of collection sites (Figure 1), the percentage of collection sites that maintain active programs, and amount of advertising. RBRC's Call2Recycling program now supports over 50,000 drop-off sites in retail locations in the United States and Canada.

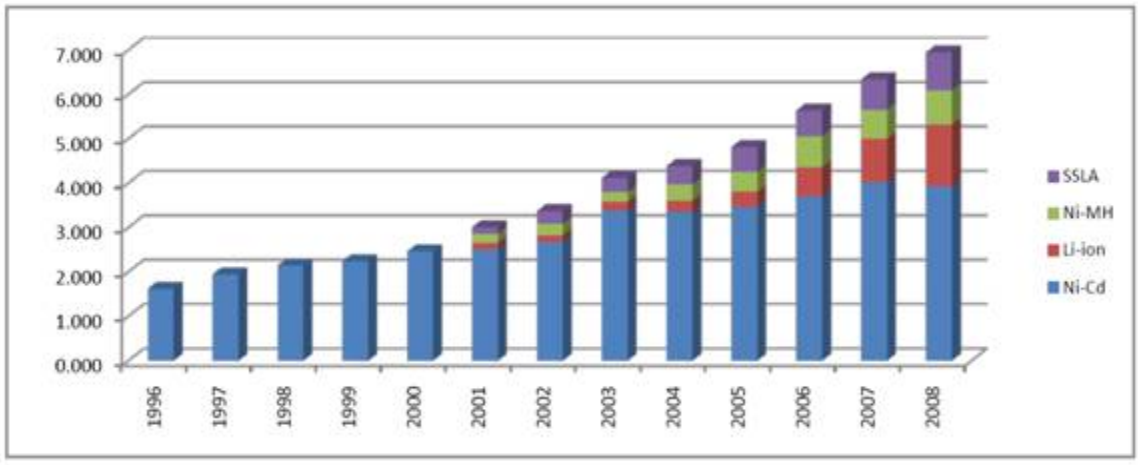
Figure 1. Location of Rechargeable Battery Collection Sites in Oregon, 2009



In terms of results, RBRC's "Year in Review" reports performance based on pounds of batteries collected on an annual basis in relationship to a base year.[5] In April of 2009, RBRC announced that it had collected over 50 million pounds of rechargeable batteries in its 15 years of operation. Seven million pounds were collected in the year 2008 alone, a 10% increase over the previous year. Figure 2 summarizes the results of RBRC collection efforts in reference to base year 1996. RBRC collected more batteries overall each year, but fewer NiCd batteries in 2008.

[5] Rechargeable Battery Recycling Corporation. 2007. *Year in Review: The Measure of Achievement*. See also RBRC's annual report, Rechargeable Battery Recycling Corporation. 2008. *Leadership, Stewardship, Partnership for Responsible Battery Recycling.*

Figure 2. RBRC Battery Collection Results, 1996-2008[6]
(millions of pounds)



RBRC Reporting for US States. Over the past two decades, eleven states and New York City have enacted laws requiring manufacturers to establish collection programs for primary and secondary batteries, as described in Table 2.[7] Two states' laws (Minnesota and New Jersey) address performance measurement and reporting, requiring manufacturers to keep track of the numbers of batteries collected and recycled. Minnesota has set a mandatory performance goal: manufacturers must recover at least 90% of batteries generated in state and report an estimated quantity of batteries sold and collected each year. New Jersey's law mandates that battery manufacturers send a biannual report to the state detailing recycling rates, but does not recommend a methodology for calculating that metric. Florida, Maryland, and New York City require manufacturers to submit performance information. Laws in Connecticut, Iowa, Maine, Rhode Island, and Vermont include no requirements in terms of performance measurement and reporting.

[6] Carl Smith, RBRC President/CEO. Personal Communication June 8, 2009.
[7] These laws address most types of rechargeable batteries and mercuric oxide primary batteries.

Table 2. Battery Performance Metrics in US State and Municipal Laws

Law (Year Enacted)	Performance Measurement Approach	Source of Performance Data
California Law[8] (2006)	"The department shall post on its Internet Web site the estimated amount, by weight, of each type of rechargeable batteries returned for recycling in California during the previous calendar year."	Department of Toxic Substances Control surveys battery recycling facilities and provides required information on website.
Connecticut Law[9] (1993)	None specified.	None specified
Florida Law[10] (2008)	Manufacturers to submit information to the state about their collection programs; no metrics specified.	Manufacturers
Iowa Law[11] (1990)	None specified.	None specified
Maine Law[12] (1995)	None specified.	None specified
Maryland Law[13] (1994)	Manufacturers must submit unit management plan. No metrics specified.	Manufacturers
Minnesota Law[14] (1995)	Manufacturers required to collect 90 percent of batteries generated in the state; must report an "**estimated amount**" of batteries sold and collected every two years.	Manufacturers
New Jersey Law [15] (1991)	"Within 15 months of the effective date of this act and at least once every six months thereafter, every manufacturer of mercuric oxide batteries or rechargeable batteries shall submit a written report to the department on used dry cell battery return or recovery rates in accordance with rules and regulations adopted by the department therefore."	Manufacturers

[8] Rechargeable Battery Recycling Act. California State Legislature. Chapter 572. July 2006.
[9] Recycling of Mercuric Oxide Batteries. Connecticut State Legislature. Title 22A, Chapter 446d. 2005.
[10] Batteries: Requirements for Consumer, Manufacturers and Sellers. Florida State Legislature. Chapter 403.7192. 2008.
[11] Land Disposal of Lead-Acid Batteries. Iowa State Legislature. Chapter 455D.10. 1990.
[12] Regulation of Certain Dry-Cell Batteries. Maine State Legislature. Chapter 24, Statute 2165. 1995.
[13] Battery Management Program. Maryland State Legislature. Title 2038, Statue 6-1101. 1994.
[14] Rechargeable Batteries and Products. Minnesota State Legislature. Chapter 115A.9157. 2008.
[15] Battery Management Plan. New Jersey State Legislature. Chapter 13:1E-99.96. 1991.

Law (Year Enacted)	Performance Measurement Approach	Source of Performance Data
New York City Ordinance[16] (2004)	Battery manufacturers must submit report on amount of rechargeable batteries collected, whether by number or by weight.	Manufacturers
Rhode Island Law[17] (2000)	None specified.	None specified
Vermont Law[18] (1992)	None specified.	None specified

RBRC routinely submits performance reports to each of the states with battery recycling laws and will prepare a report for any state that requests performance information. Table 3 is the report RBRC prepared for the New Jersey Department of Environmental Protection in 2008. Each of the reports RBRC prepares for states follows the same format and includes the following information for the previous calendar year: the number of sites in the state that have agreed to collect batteries, the number and percentage of those sites that maintain active collection programs, total pounds of rechargeable batteries collected, pounds collected of each rechargeable battery type, pounds of "non-conforming" rechargeable batteries collected, pounds and number of cell phones collected, and other material collected. Even though Minnesota's law requires collection results to be referenced to the number of batteries sold and New Jersey's law requires reporting in terms of a "recycling rate," RBRC reports do not include such reference points.

Table 3: RBRC State Performance Report for New Jersey[19]

New Jersey: Receipt Report for 1/1/2008 through 12/31/2008
Active Sites - 1,490
Number of Sites with Receipts - 461 (30.94%)
Total Receipts - 2,292
Pounds Received - 85,549.00 (38.19 tons)
Conforming Rechargeables - 82,637 lbs
- NiCd - 47,495 lbs
- Li-Ion - 10,456 lbs
- Ni-MH - 8,190 lbs
- Lead - 16,496 lbs
Non-Conforming Rechargeables - 2,101 lbs
Pounds Cell Phones - 695 lbs
Number of Cell Phones - 2,736
Other Materials - 116 lbs

[16] Recycling Program for Rechargeable Batteries. New York City Legislature. Local Law 97. 2005.
[17] Battery Deposit and Control. Rhode Island State Legislature. Chapter 23-60. 2000.
[18] Regulation of certain dry-cell batteries. Vermont State Legislature. Chapter 159, Statute 6621B. 1992.
[19] RBRC. 2009. Reports on performance of state battery programs available upon request.

Battery Council International.[20] Battery Council International is the trade association for the lead-acid battery industry.[21] Of the metrics we considered, BCI's approach is perhaps the most relevant to the goals of battery recycling programs, and the data used are of particularly high quality. While RBRC measures and reports performance based on program convenience and collection results referenced to a baseline year, Battery Council International's (BCI's) measures performance based on a recycling rate, that is, the amount of a specific material (battery lead) recycled compared to the amount of battery lead available for recycling. Table 4 describes BCI's approach, assumptions, and data. The figure for total pounds of lead recycled from batteries is gathered from questionnaires provided to secondary lead smelters. The figure for total pounds of lead available for recycling is calculated as a function of battery shipments, battery exports, vehicle imports, and vehicle exports. The sum of battery exports and vehicle exports is subtracted from the sum of battery shipments and vehicle imports to determine the number of batteries consumed domestically. Multiplying this number by the average lead weight content of the particular battery type yields the total pounds of lead consumed domestically and available for recycling. To adjust for battery lifespan, all total figures are aggregated from a five-year span between 1997 and 2001.

Table 4. BCI Battery Collection Rate Methodology

<table>
<tr><th>Approach</th><th colspan="2">Assumptions</th><th>Data</th></tr>
<tr><td rowspan="4">Performance to be measured based on the recycling rate of lead available from lead-acid batteries in the US

Recycling rate = (battery lead recycled/battery lead available for recycling) x 100</td><td colspan="2">Battery lead available for recycling = (1) Battery shipments - (2) battery exports + (3) vehicle imports - (4) vehicle exports</td><td rowspan="4">Quantities of battery lead recycled determined from questionnaires sent to all secondary lead smelters

Quantities of battery lead available for recycling from BCI's statistical database (for battery shipments), US Department of Commerce (for battery exports and vehicle exports), and the Automotive Aftermarket Industry Association (for vehicle imports)</td></tr>
<tr><td>Battery Weights</td><td>Average lead weight applied to each battery category</td></tr>
<tr><td>Battery Lifespan</td><td>2-10 years depending on battery type</td></tr>
</table>

European Battery Stewardship Organizations. The European Commission regulates end-of-life battery management through a series of directives, the most recent of which was the Directive on Batteries and Accumulators and Spent Batteries and Accumulators (EU Battery Directive

[20] Battery Council International. 2003. *National Recycling Rate Study*. http://www.solidwastedistrict.com/stats/recyling_rate_study_july_2003.pdf

[21] Lead-acid batteries are used to start engines and provide long-term sources of power for large machines such as boats and trailers.

2006/66/EC) enacted September 6, 2006.[22] In addition to restricting the use of mercury in batteries, this directive requires battery producers to establish collection and recycling programs for used "portable batteries" (primary and secondary batteries).[23] National battery collection and recycling organizations measure and report performance with a wide array of convenience and results performance metrics, as shown in these organizations' annual reports. In terms of convenience, French battery collection and recycling organizations note that they operate more than 33,000 individual battery collection sites,[24] and German GRS Batterien reports providing over 400,000 battery collection bins to retail locations annually.[25] In the United Kingdom, Battery Back operates 1200 free collection points and plans to offer an additional 80,000 collection sites soon.[26] In Belgium, BEBAT runs over 20,000 collection sites in retail locations, schools, businesses and recycling centers.[27] Spain's ECOPILAS program currently operates 4,000 collection sites and aims to increase to 30,000 by 2011.[28] German and French battery organizations also report the percentage contribution of the three major collection channels: retail sites, municipalities, and industrial locations.

In addition to convenience measures, these organizations share results referenced to sales and population, as shown in Table 5. Such measures allow comparison among programs. Germany and France are currently the leaders among European countries in portable batteries collected, having gathered over 14,000 and 10,000 tonnes respectively in 2007. Collection efforts in Belgium brought in 2,560 tonnes that year, over half of the batteries sold. Despite selling approximately as many batteries as both Germany and France, the United Kingdom reports collections of only 1,000 tonnes. Collection rates vary from a high of 54% in Belgium to a low of about 1% in Italy. Similarly, grams collected per capita range from a high of 240 in Belgium to 1.4 in Italy.

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[22] Directive 2006/66/EC of the European Parliament and of the Council on batteries and accumulators and waste batteries and accumulators and repealing Directive 91/157/EEC. September 6, 2006. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:266:0001:0014:EN:PDF

[23] The EU Directive defines "portable batteries" as batteries that are sealed, can be hand-carried, and are neither industrial nor automotive batteries.

[24] ADEME. *Piles et Accumulateurs/Données 2007*. (In French) http://www2.ademe.fr/servlet/getDoc?cid=96&m=3&id=57810&p1=6456&p2=&ref=17597. Of the 33,000 collection sites, 84% are situated at retail locations, 10% at industrial locations, and 4% at waste management centers.

[25] GRS Batterien. *Annual Review 2008*. http://www.grs-batterien.com/fileadmin/user_upload/Download/Englisch/Erfolgskontrolle/Success_Monitor_08.pdf. The retail channel represents 46% of the batteries collected. Over 80,000 larger bins were distributed for use in recycling centers and in industrial and business locations, representing 23% and 31% of the total batteries collected, respectively.

[26] Battery Back. *Battery Recycling Regulations*. http://www.batteryback.org/battery-compliance.html

[27] BEBAT. *General Information – Collection Network.* http://www.bebat.be/pages/en/main.html

[28] ECOPILAS. ASIMELEC espera llegar a 30.000 recopiladores. January 2009. (in Spanish) http://www.ecopilas.es/media/ECOPILAS%20marzo%2009/Infoenviro1marzo2009.pdf

Table 5. Battery Collections (in tonnes) in Selected European Countries (2007)

	Batteries sold (in 2007)	Batteries collected	Collection Rate (annual collections compared to annual sales)	Grams recycled per capita
Germany[29]	33,225	14,132	43%	171 grams/capita
France[30]	32,200	10,334	34%	163 grams/capita
United Kingdom[31] [32]	≈30,000	≈1,000	3%	16.4 grams/capita
Belgium [33]	4,700	2,500	54%	240 grams/capita
Italy[34]	≈28,000	81	+/- 1%	1.4 grams/capita
Spain[35]	≈15,000	2,500	16%	56.6 grams/capita

The European Union's approach to measuring and reporting performance is stipulated in its 2006 Directive and in subsequent decisions aimed specifically at defining performance assessment methods. The most recent decision (2008/763/EC), issued September 29, 2008, states that the European Commission will assess performance based on the collection rate for batteries. The amount available for collection is based on the weight of batteries placed on the market in the member state in the year concerned, excluding batteries that have left that state.[36] In order to sell batteries in the European market, battery manufacturers must register with member governments and submit information on battery sales on an annual basis. National battery collection and recycling organizations use sales data to set members' financial

[29] GRS Batterien. *Annual Review 2007*. http://www.grs-batterien.com/fileadmin/user_upload/Download/Englisch/success_engl.pdf
[30] ADEME. *Piles et Accumulateurs/Données 2007*. (In French) http://www2.ademe.fr/servlet/getDoc?cid=96&m=3&id=57810&p1=6456&p2=&ref=17597
[31] ENDS Europe. *EBRA – Ten Years of Battery Recycling in Europe.* October 2008. http://www.endseurope.com/docs/81020a.pdf
[32] Battery Back. *Battery Recycling Regulations*. http://www.batteryback.org/battery-compliance.html
[33] ENDS Europe. October 2008. (FN 31)
[34] ENDS Europe. October 2008. (FN 31)
[35] ENDS Europe. October 2008. (FN 31)
[36] Commission Decision establishing, pursuant to Directive 2006/66/EC of the European Parliament and of the Council, a common methodology for the calculation of annual sales of portable batteries and accumulators to end-users. September 29, 2008. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:262:0039:0039:EN:PDF

contributions toward covering the costs of collecting and recycling batteries. Because the volume of a manufacturer's sales is linked to the fees it pays, manufacturers have an incentive to understate sales. National battery collection and recycling organizations customarily audit information on battery sales submitted by member companies to ensure that information is complete and accurate.[37] The fact that an estimated 70 to 95% of rechargeable batteries are sold to manufacturers of cell phones, cordless power tools, laptop computers, and other devices requiring a portable power source – and not directly to consumers – makes calculation of battery sales more difficult.[38] These manufacturers may be based outside the European Union and sell to customers throughout the world. Ensuring their awareness of and compliance with European battery reporting requirements is a challenge for national battery organizations.

The European Commission has set "collections-to-sales" performance goals of 25% by September 26, 2012 and 45% by September 26, 2016. Belgium, Germany, and France have already exceeded the goal for 2012 and Belgium has exceeded it for 2016. Italy, the United Kingdom, and Spain still have a long way to go.

Table 6. European Union Battery Collection Rate Methodology

Approach	Assumptions	Data
Performance to be measured based on the **collection rate** defined as the amount collected compared to "the weight of …batteries … placed on the market in the territory of the Member State in the year concerned, excluding … batteries …that have left the territory of that Member State in that year before being sold to end-users."[39]	• Sales in the year of concern are an appropriate proxy for batteries available for collection. • Average battery weight is the unit of analysis	Battery sales data (by type) are available in aggregate from national organizations of battery manufacturers and importers.

European battery collection and recycling organizations also measure performance based on what happens to batteries following collection. After all, appropriate end-of-life management does not end with collection but requires that the metals batteries contain be recycled for future application as raw material or properly disposed. The European Commission has set recycling efficiencies for batteries of 75% by average weight for NiCd batteries, meaning that

[37] To address the problem of incomplete or inaccurate reporting of sales data, the European Portable Battery Association recommends that battery collection and recycling organizations "work with an external auditor to control the accuracy of the submitted data and to check regularly the governance of the [collection organization]." EPBA. 2007. *Compliance Blueprint: A Guidance Document for Setting Up a Battery Collection Organization*. http://www.epbaeurope.net/documents/ComplianceBlueprint_July2007_000.pdf.

[38] Evaluserve. 2009. *Market Share Analysis for Portable Battery Market in the US & Canada.*

[39] EU Battery Directive 2006/66/EC, FN 22.

for each NiCd battery collected, 75% must be recycled into other products.[40] Similarly, the European Commission requires a recycling efficiency of 65% by average weight for lead acid batteries and 50% by average weight for all other batteries. The GRS Batterien reports a recycling efficiency of 92% of the batteries it collected in 2007.[41] Representatives of member states are currently developing a methodology for calculating these rates to ensure consistency throughout the European Union.[42]

Emerging Battery Collection Metrics

As public policy in North America moves toward greater emphasis on extended producer responsibility for batteries, metrics for assessing program performance are emerging in various jurisdictions, particularly in Canada. Environment Canada and Stewardship Ontario utilize a "collections-to-sales" approach much like those required in the European Union, however these Canadian approaches include specific lifespan and hoarding assumptions for each battery type.

Stewardship Ontario.[43] Stewardship Ontario has proposed to measure the performance of battery collection programs based on the ratio of batteries collected to batteries available for collection, as shown in Table 7. Whereas the volume collected is ascertained from Stewardship Ontario's sorting and recycling center data, Stewardship Ontario determines the amount available for collection using several key pieces of information. The total tonnage supplied for use[44] in Ontario in a given year is extrapolated from data in an Environment Canada and Natural Resources Canada report titled "Battery Recycling in Canada – 2008 Update."[45] Ontario's population during the years 1991 to 2009, when batteries available for collection today were sold, was about 35% to 39% of the Canadian population overall; Stewardship Ontario has applied these percentages to Canadian battery sales estimates to determine amounts available for collection in Ontario. This information is then supplemented with assumptions on individual battery lifespan and battery hoarding practices. Most consumer batteries last between 1.75 and 5 years depending on the chemical formulation. The assumptions on battery hoarding, drawn from the Battery Flow Model of the same

[40] Recycling efficiencies are described in Annex III of EU Battery Directive 2006/66/EC, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:266:0001:0014:EN:PDF

[41] GRS Batterien. *Annual Review 2007*. http://www.grs-batterien.com/fileadmin/user_upload/Download/Englisch/success_engl.pdf

[42] For information on EU efforts to develop a methodology for calculating battery recycling efficiencies, see Consortium ESWI: **E**xpert Team to **S**upport **W**aste **I**mplementation. 2009. *Study on the Calculation of Recycling Efficiencies and Implementation of Export Article (Art. 15) of the Batteries Directive 2006/66/EC.* http://www.bipro.de/batteries-directive/sub/projects.htm.

[43] Stewardship Ontario. *Draft Preliminary Consolidated MHSW Program Plan – Volume 2: Material Specific Program Plans*. July 8, 2009 The Stewardship Ontario program addresses all battery types with the exception of lead-acid batteries from vehicles.

[44] Batteries "supplied for use" are batteries that reach Ontario consumers.

[45] Because this report is not publicly available at this time, we have not been able to review it.

Environment Canada and Natural Resources Canada report, indicate that 30% of primary batteries and 60% of rechargeable batteries are hoarded after use. To adjust for variations in hoarding time, the Battery Flow Model calculates two separate figures for quantity available for collection based on a 5-year and a 15-year hoarding scenario.[46] The term "available for collection" implies that the battery will not be stored or reused and has been discarded for recycling.

Table 7. Stewardship Ontario Battery Collection Rate Methodology

Approach	Assumptions		Data
Performance to be measured based on collection rate of all batteries, excluding lead-acid batteries from vehicles, in Ontario Collection Rate = (amount collected / amount available for collection) x 100	**Battery Lifespan**	Primary Batteries: 3 years NiCd: 5 years Li-Ion: 1.75 years Ni-MH: 3 years SSLA: 5 years	- Quantity supplied for use extrapolated from data in the Environment Canada and Natural Resources Canada Report: "Battery Recycling in Canada – 2008 Update." - Quantity available for collection ascertained from quantity supplied for use with adjustments for battery lifespan and hoarding. - Quantity collected determined from figures from collection sites and collection events.
	Battery Hoarding	-30% of primary batteries are hoarded at end-of-life. -60% of rechargeable batteries are hoarded at end-of-life. Two Scenarios Used for Battery Flow Model: Low hoarding rate = 5 years High hoarding rate = 15 years	

Stewardship Ontario has set a collection rate target of 20% in year one of the program and 25% in year two. Targets increase by 5 percentage points annually to achieve a 45% collection rate in year 6. While these targets are aligned with those of the European Union, Stewardship Ontario's methodology for calculating the batteries available for collection includes different lifespan and hoarding assumptions from European Union's simple "collections-to-sales" approach. As a result, the targets are not completely comparable.

[46] RBRC has disputed these assumptions, citing Belgian and French studies that find much higher hoarding rates. RBRC. 2008. "The Challenge of Calculating Portable Rechargeable Battery Recycling Rates." White Paper.

Stewardship Ontario has also set recycling rate targets: 37% for primary batteries and 60% for rechargeable batteries. Stewardship Ontario does not explain how it calculates recycling rates other than to note that the United Kingdom's national battery recycling program BatteryBack considers neither waste-to-energy nor slag operations as recycling. We assume that Stewardship Ontario also excludes those activities from its definition of recycling.

Rechargeable Battery Recycling Corporation of Canada.[47] The Rechargeable Battery Recycling Corporation of Canada (RBRCC) has explored battery collection rate calculations from a different angle from most other groups involved in battery collection efforts. Whereas the European Union and Environment Canada calculate collection rate as a relationship between the amount collected and amount sold, RBRCC recommends that performance be assessed based on the amount of battery waste collected for recycling in comparison to the total amount of battery waste present in the municipal solid waste stream. European battery manufacturers also support this "collections-to-waste" approach. Since a goal of battery collection and recycling programs is to prevent batteries from being disposed of in landfills and incinerators where they can contaminate air, water, and land, their presence in the waste stream is a relevant performance criterion. The total amount of batteries available for recycling consists of both batteries collected as well as batteries disposed of in landfills. This calculation requires that samples from landfill deposits analyzed for battery content and levels of harmful heavy metals such as cadmium, lead, and mercury.[48] By focusing only on the presence of batteries in the municipal solid waste stream at a given time, RBRCC avoids having to make assumptions about battery lifespan and hoarding required in a collection-to-sales approach. Table 8 summarizes the RBRCC approach.

Table 8. RBRCC Battery Collection Rate Methodology

Approach	Assumptions	Data
Performance to be measured based on **recycling rate** of portable rechargeable batteries in municipal solid waste (MSW) MSW Recycling Rate = (Total Battery MSW Recycled / Total Battery MSW Generated [for recycling and disposal]) x 100	- All rechargeable batteries eventually reach the MSW stream. - Landfill deposits are available for analysis. - Reliable data exist on the amount of batteries collected for recycling.	- The total mass of batteries disposed of as trash is determined from landfill deposit samples. - The total mass of batteries collected for recycling is determined from recycling centers' figures.

[47] Ibid.
[48] See RBRC. 2007. *A Cooperative Study of the Rechargeable Battery Content of Municipal Solid Waste in North America.*

Collection and Recycling Metrics for Other Consumer Products

Governments, industry-run product stewardship organizations, and environmental organizations in the United States and Canada are developing metrics to evaluate the performance of programs that collect and recycle mercury thermostats, electronics, and auto switches. The ways that stakeholders have chosen to evaluate these programs helps to inform methods for assessing battery collection and recycling programs. Measuring the performance of product stewardship initiatives for mercury thermostats, electronics, and auto switches poses particular challenges due to uncertainty about how long these products remain in use and how long consumers hold on to them after they stop using them. These challenges are common to battery product stewardship programs as well.

Mercury thermostats

For decades, thermostat manufacturers used mercury in thermostats used in homes and commercial buildings. Each mercury thermostat contains about 4 grams of mercury, making thermostats a major potential source of mercury contamination. As shown in Table 9, governments and manufacturers have proposed a variety of approaches for measuring the performance of programs that collect out-of-service mercury thermostats. A majority of government stakeholders now favor a results-based approach that compares the number of mercury thermostats collected to the number available for collection. While there is still debate as to the best reference point for determining the number available for collection, many states now consider the number of thermostats sold for replacement as the most appropriate comparison.

Maine's Department of Environmental Protection (ME DEP) calculates the number of thermostats available for collection based on the number of commercial and residential building units in the state, information that is available from the US Census. Maine assumes that each commercial building unit contains 1.25 thermostats and each residential building unit contains 1.5 thermostats. It further assumes that the lifespan of a thermostat is 30 years and that 83% of thermostats coming out of service contain mercury.[49]

King County, Washington, bases the number of mercury thermostats available for collection on a survey of mercury thermostats in commercial buildings it conducted in 2005.[50] King County

[49] Maine Department of Environmental Protection. 2004. A Plan to Improve the Collection of Mercury Thermostats. http://www.maine.gov/dep/rwm/publications/legislativereports/pdf/thermostatreport.pdf. See Calculations of Mercury in Maine Thermostats and Annual Waste Stream Amounts, p. 14.

[50] Local Hazardous Waste Management Program in King County. 2005. *Mercury Thermostats in Commercial Building in King County*

researchers found that the presence of a mercury thermostat correlates with building age and heating type. They have used that relationship to develop a predictive model. With information about the age and heating source of buildings in a given area, they estimate the number of thermostats containing mercury. King County assumes that the lifespan of a mercury thermostat is 50 years.

In 2008 the Product Stewardship Institute, Inc. (PSI) convened stakeholders to review the assumptions underlying Maine's and King County's performance metrics and develop a metric that would provide a sound basis for policy.[51] Most of those participating in this process supported a collection rate based on the number of thermostats *sold for replacement*. Basing the collection rate on the number of thermostats sold for replacement avoids having to make assumptions about thermostat lifespans. Policymakers must still make assumptions about the percentage of thermostats coming out of service that contain mercury. PSI plans to work with heating and cooling equipment contractors to track the number of thermostats they remove that do and do not contain mercury.

The Thermostat Recycling Corporate (TRC), the product stewardship organization established and operated by thermostat manufacturers to collect and recycle mercury thermostats, recommends that states assess performance based on annual increases in mercury thermostat collections. TRC's most recent annual report includes information about the number of mercury thermostats collected in the U.S. for the period 1998-2008.[52]

[51] Summaries of these meetings, and more information about the collection rate methodology, are available on the PSI website, http://www.productstewardship.us/displaycommon.cfm?an=1&subarticlenbr=108

[52] Thermostat Recycling Corporation. 2008. *Annual Report 2008*. http://thermostat-recycle.org/files/2008%20TRC%20Annual%20Report.pdf

Table 9. Approaches to Measuring the Performance of Mercury Thermostat Collection Programs

Proponent	Approach	Assumptions	Data source
ME DEP	Collection rate with # of buildings in state as reference point	• Residential buildings contain 1.5 thermostats and commercial buildings contain 1.25 thermostats • Thermostat lifespan is 30 years • 83 % of thermostats contain mercury	US Census: # of residential and commercial buildings
King Co, WA	Collection rate with # of mercury thermostats observed in commercial buildings as reference point	• Commercial buildings are an appropriate proxy for buildings generally • Thermostat lifespan is 50 years	Survey of commercial buildings in King County
PSI	Collection rate with sales for replacement as reference point	• 83% of thermostats contain mercury (precise percentage to be determined through PSI contractor survey)	Frost & Sullivan: # of thermostats sold for replacement
TRC	Absolute collections or collections compared to base year		TRC collections

Electronics

Nineteen states and New York City have passed legislation requiring collection and recycling of electronics.[53] Several state laws include recycling rate metrics for assessing the performance of electronics take-back programs. Minnesota's and Indiana's laws (signed into law in 2007 and 2009, respectively) determine the amount available for collection based on sales of targeted electronics for the previous calendar year. For example, Minnesota requires manufacturers to recycle 80% by weight of the video display devises they sold in the previous year. New York City's law, enacted in 2008, requires manufacturers to achieve recycling rate targets based on average sales over the previous three-year period: in 2012, they must recycle 25% of sales (from previous 3 years), and in 2018, they must recycle 65% of sales (from previous 3 years). In contrast, New Jersey's law (enacted in 2008) bases performance of its electronics recycling program on per capita collections, and Oregon's law (enacted in 2007) sets a convenience metric of at least one collection site in every county and at least one collection site for any city

[53] Electronics Take-Back Coalition. 2009. *Brief Comparison of State Laws on Electronics Recycling*. http://www.electronicstakeback.com/legislation/Compare_state_laws_chart.pdf

with a population of 10,000. Many early laws, such as Maine's law enacted in 2004 and Maryland's law enacted in 2005, do not address performance metrics.

Auto Switches

In the past, automakers used mercury in convenience light switches in dashboards, trucks, and other storage spaces. Each switch contains about 0.8 grams of mercury. When vehicles reach end-of-life, these switches need to be removed before vehicles are shredded. In 2006, EPA announced a national program to recover mercury switches from scrap automobiles, the National Vehicle Mercury Switch Recovery Program (NVMSRP). All states participate in the program, with the exception of Maine which runs its own, comparable effort.

The basis for the NVMSRP is a memorandum of understanding signed by governments and all major US automakers.[54] Among other requirements, the MOU stipulates that automakers report quarterly on state and national capture rates – meaning the number of switches collected compared to the number available for collection. To determine the number of mercury auto switches available for collection, governments and automakers have worked collaboratively to develop a Switch Retirement Model.[55] The model is based on the number of vehicles registered in a state, the number of mercury switches per vehicle, and automobile scrappage rates. To estimate the second variable – the number of mercury switches per vehicle – automakers undertook the "Michigan Mercury Switch Program" to establish which vehicle years, makes, and models contained mercury switches.

The automotive industry created the End of Life Vehicle Solutions Corporation (ELVS) to meet the requirements of the program. ELVS reports to states include the following information:[56]

- Number of mercury switches collected
- Amount of mercury contained in the collected switches
- Capture rate
- Estimated number of vehicles manufactured containing mercury switches
- Estimated number of vehicles that have been recycled

[54] Memorandum of Understanding to Establish the National Vehicle Mercury Switch Recovery Program, August 11, 2006, http://www.epa.gov/mercury/pdfs/switchMOU.pdf

[55] End of Life Vehicle Solutions Corporation ELVS. 2009. Switch Retirement Model Version 2 February 2009.

[56] See, for example, ELVS report to the Iowa Department of Natural Resources, "End of Life Vehicle Solutions Corporation Annual Manufacturers' Implementation Report," available at http://www.iowadnr.gov/waste/recycling/files/elvs_08annualreport.pdf

Recommendations for Best Practice

In choosing an appropriate performance metric or set of metrics, it is important to keep in mind the reasons why performance measurement is worth undertaking: to motivate performance improvement, facilitate comparison and learning, demonstrate commitment to program outcomes, and satisfy regulatory requirements. Battery recycling metrics in use today in the United States and Canada address aspects of the convenience of battery recycling programs, but not how well they are performing. To fill that gap, we offer the following recommendations.

1. Measure performance based on a collection rate.

A collection rate that compares the amount of primary and secondary batteries collected to the amount available for collection is critical because it indicates the success of the collection effort in relationship to the scope of the collection problem. Performance metrics RBRC currently uses appear not to satisfy regulatory requirements in New Jersey and Minnesota which require reporting in terms of collection rates. Basing performance on a collection rate would bring battery manufacturers into compliance with these laws.

A consensus is emerging that battery sales are the most appropriate basis for estimating amounts available for collection. All European Union member states have adopted a "collections-to-sales" approach, and Environment Canada and Stewardship Ontario support it as well. The chief areas of controversy appear to be assumptions about battery lifespan and consumer hoarding that are implicit in the European model and explicit in the Canadian models. The fact that the significant majority of rechargeable battery sales -- 70 to 95% -- are to equipment manufacturers, as opposed to consumers, further complicates efforts to measure the performance of battery stewardship programs. PSI is not in a position to recommend the most appropriate assumptions with respect to lifespan and hoarding. Instead, we recommend that battery manufacturers convene a stakeholder process to determine the best assumptions, taking into account ease of use and data quality, as noted in recommendation 9.

Adopting a "collections-to-sales" approach will allow North American battery manufacturers to "speak the same language" as emerging and established battery collection efforts. While battery manufacturers may maintain that a "collections-to-waste" approach is more relevant, adoption of this approach as the sole performance metric would undermine comparison and learning among programs already committed to using sales as their reference point.

2. Add a per capita collection metric.

In addition to a collection rate metric, we recommend that performance also be assessed based on per capita collections in every US state and Canadian province. Per capita collection information would help manufacturers determine which programs are exemplary and should be replicated. Manufacturers could then better assess the top performing programs for key elements of success to transfer to lower-performing states and provinces.

3. Continue to measure and report program convenience.

Convenience metrics are important because they communicate the ease with which the public can access battery recycling programs. This metric is valued by state and local governments, and RBRC should continue to use it, in addition to the others proposed here.

4. Motivate performance by adopting a collection rate goal.

While the purpose of this report is not to recommend specific performance goals, the setting of a performance goal communicates commitment to performance improvement. Measurement in the absence of a goal leaves the work half-done. The goal should be based on collections referenced to sales. The numeric goal (e.g., 50% by 2012) should be determined through a stakeholder process and should be included in legislation or established agency administrative processes.

5. Include verified sales data for all battery types in RBRC annual reports.

Sound performance metrics are based on high-quality data that are collected in accordance with established practice and can be verified. Data quality is one of the major challenges in the development of a sound performance metric for battery collection and recycling. Manufacturers can play a key role in providing data and enabling verification. Manufacturers should authorize RBRC to publish industry sales data for both primary and secondary batteries, by state and province. Protocols should be established to ensure the quality of reported data. These protocols should include third-party verification.

6. Share information about the fate of collected batteries: where they are sent for processing, how they are processed, and the fate of all materials.

Collection is not the end of the story. What happens to batteries after collection is of great importance to environmental protection. Recovery rate (amount recycled compared to amount collected) and recycling rate (collection rate multiplied by recovery rate) are emerging metrics that communicate the extent to which battery stewardship programs are "closing the loop" and using spent batteries as inputs to new products. RBRC should

disclose, audit, and verify information on the fate of the batteries it collects through its Call2Recycling prams.

7. Standardize definitions for collection rate, recovery rate, and recycling rate, across battery programs, as well as other product stewardship initiatives.
Currently, usage of these terms is inconsistent. Common definitions would help to facilitate comparison among battery programs and informed debate about appropriate metrics.

8. Consider a sustainability metric for batteries.
Largely missing from discussions about battery performance metrics is any consideration of the full life cycle impacts of battery recycling, including greenhouse gases, toxicity, energy use, and other variables associated with battery manufacturing, transportation, use, and recycling. We recommend that battery manufacturers commission a lifecycle assessment to understand the circumstances under which the different types of batteries should be recycled or disposed.

9. Create an advisory committee on performance measurement and reporting
Battery manufacturers should establish an advisory committee on performance measurement and reporting to review metrics on a periodic basis and determine the need for third-party verification review. As an initial step, manufacturers should convene monthly or quarterly conference calls with a stakeholder group to share information and refine the measurement process over time. Performance metrics for batteries should not be thought of as static but should evolve to take into account new products, data sources, environmental concerns, and understanding of consumer behavior.

Conclusion

Performance has many dimensions. It includes program convenience, collection results, post-collection management, and sustainability, as summarized in Table 10. In North America, RBRC's extensive collection programs have earned it recognition among states and local governments, retailers, consumers, and other stakeholders. Its performance reporting of convenience and results relative to a base year are noteworthy. But battery collection performance with respect to the metric of greatest relevance to those who care about battery recycling most – the extent to which batteries are entering the solid waste stream and potentially contaminating the environment – is unknown. We urge battery manufacturers to convene a group of stakeholders to agree on a set of appropriate performance metrics, develop goals, and establish processes for auditing, verification, and ongoing communication. Metrics should include collection rates compared to sales, collections per capita, and recycling rates, as well as convenience.

Table 10. Recommended Product Stewardship Metrics

Performance Category	Key Indicators
Program Convenience	• Number of active collection sites relative to population, hours of operation, cost (if any) to participate • Proximity of target population to collection drop-off • Public awareness of collection programs
Collection Results	• Absolute collection relative to baseline • Absolute collection per capita • Collection rate
Post-collection management	• Recovery rate • Recycling rate
Sustainability	• Life cycle economic, environmental, and social costs and benefits