Electronics Environmental Benefits Calculator

Version 1.0

A Tool to Measure Benefits of Life Cycle Management of Computers

FINAL REPORT

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Submitted by

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ABSTRACT

This report presents the Electronics Environmental Benefits Calculator (EEBC), which has been designed to allow institutional purchasers and the federal government to quantify the benefits of purchasing products registered under the Electronic Product Environmental Assessment Tool (EPEAT) program and of improving the operation and end-of-life management of computers. The project resulted in a user-friendly spreadsheet-based tool that calculates savings in energy, emissions, material use, wastes, and cost associated with the purchase, use and end-of-life management of computers. The project was funded through a Cooperative Agreement between the University of Tennessee and the U.S. Environmental Protection Agency, with the primary research team of Abt Associates and Dillon Environmental Associates developing the tool through sub-awards.

I. INTRODUCTION

In recent years, the U.S. Environmental Protection Agency (EPA) has developed several programs designed to improve the management of electronic assets within the federal government and to drive the marketplace to design environmentally preferable electronic products. Two notable federal efforts are the Electronic Product Environmental Assessment Tool (EPEAT) and the Federal Electronics Challenge (FEC). EPEAT, a tool for evaluating the environmental performance of computer products, was developed to meet the growing demand by large institutional purchasers, including federal and state government, to buy greener electronic products. EPEAT includes mostly criteria for product design, while addressing some operations, maintenance, and end-of-life (EOL) management issues. After almost three years in development, the EPEAT program began registering its first products in mid-2006. Manufacturers submit products for registration, and depending on the number of EPEAT criteria they meet, their products may be designated as EPEAT bronze, silver or gold[1]. The FEC is a voluntary partnership program that encourages federal facilities and agencies to purchase "greener" electronic products, reduce impacts of product use, and manage obsolete equipment in an environmentally safe manner[2]. The FEC incorporates EPEAT as its main procurement tool.

These federal programs are intended to encourage environmentally sound purchasing, use and EOL management decisions; yet, they do not have methods of quantifying the environmental and economic benefits derived from the program activities. Publicly available tools and evaluation methods (see Section II B) were reviewed to determine whether they were adequate for calculating benefits from these programs. There is currently no single tool that meets the needs of and covers the scope of issues of the FEC and EPEAT. Thus, the Electronics Environmental Benefits Calculator Tool (EEBC) was developed to quantify total benefits from the purchase, operation and EOL management of computers (desktop or notebook), as might be purchased or managed under the EPEAT and FEC programs. This report reviews the development, structure, features and outputs of the EEBC, Version 1.0, which was developed by Abt Associates and Dillon Environmental Associates through sub-awards to a cooperative agreement between the University of Tennessee and the U.S. Environmental Protection Agency.

II. METHODOLOGY

A. Identify Purpose and Goals of the Tool

The EEBC was developed to quantify total benefits from the purchase, operation and EOL management of desktop and/or notebook computer systems. The goal in developing the EEBC was to provide a simple-to-use, transparent, flexible, modular, upgradeable and adaptable tool that could be available concurrently with the implementation of the EPEAT program and the availability of data from partners in the FEC program.

The tool is intended to have two major uses: (1) as a reporting tool (e.g., reporting benefits of purchases made or EOL management activities such as recycling); and (2) as a planning tool (e.g., comparing benefits associated with

[1]Electronic Product Environmental Assessment Tool (EPEAT) website: http://www.epeat.net/.
[2]Federal Electronics Challenge (FEC) website: http://www.federalelectronicschallenge.net/.

purchasing options or EOL activities). The primary intended audience of the EEBC is the institutional user. The EEBC will assist institutional purchasers in measuring the environmental and economic benefits of purchasing EPEAT-registered products as well as managing products in service and obsolete equipment. As an example, a purchaser can simply enter the number of EPEAT-registered products purchased, and the calculator tool will provide a breakdown of the resulting environmental benefits. The ability to demonstrate achievements will help justify potential price premiums for "greener" electronics and allow purchasers to communicate the environmental results of their procurement efforts.

Concurrent with the development of these federally sponsored programs in the United States is the growing interest by the U.S. government to measure the benefits and impacts of its initiatives, including environmental programs and expenditures. Thus, the EEBC can also be used by government to quantify the overall benefits of the EPEAT and FEC programs by demonstrating the aggregated environmental benefits resulting from the sale of EPEAT-registered products and from reuse or recycling federal electronic assets. Since the FEC program measurements are generic activities (e.g., power management, equipment reuse and recycling), the calculator tool can be used by any institution interested in quantifying benefits of improving use-phase and EOL management of electronic equipment.

Other users of the tool may include manufacturers who are developing or marketing products that meet EPEAT criteria. The tool could inform the manufacturers of the benefits associated with a product meeting one set of criteria versus another set.

B. Evaluate Other Tools

To assist in defining the structure and functionality of the tool, related and publicly available tools were reviewed, such as:

- The European Union's (EU) EPIC-ICT, which is developing environmental performance indicators for information and communication technology (ICT) products, using personal computers as an example[3];
- U.S. EPA's ReCon Tool, which calculates greenhouse gas (GHG) emissions and energy consumption related to purchasing and/or manufacturing activities using baseline and alternative recycled-content scenarios[4];
- U.S. EPA's Waste Reduction Model (WARM), which calculates energy use and GHG emissions of baseline and alternative waste management practices across a wide range of material types, including personal computers[5];
- U.S. EPA's Energy Star® Savings Calculators, which estimate the annual life-cycle environmental benefits and cost savings associated with purchasing Energy Star® qualified computers and monitors[6]; and
- The EU RELIEF project, which was a European research project on green purchasing that addressed purchasing across many industry sectors, including computers, and was concluded in 2003[7].

Relevant characteristics from each of these tools or projects were considered for the EEBC tool: for example, which metrics to calculate as benefits, and how to structure the user interface and present the outputs of the tool. Given the goals and resources available for the EEBC tool, the different strengths of each were considered and applied, if appropriate, during development of the tool.

C. Select EPEAT and FEC Criteria

The EPEAT and FEC programs specify product design and management criteria based on environmental attributes (e.g., the elimination of toxic chemicals, the use of recycled materials, power consumption) or program activity (e.g., equipment reuse and recycling). The EEBC translates selected EPEAT and FEC criteria and activities into quantifiable environmental benefits, based on readily available user input and default assumptions. The benefits are based on comparing the products purchased to an industry average baseline product.

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[3] EPIC-ICT website: http://www.epic-ict.org/.
[4] Recycled Content (ReCon) Tool website: http://yosemite.epa.gov/oar/globalwarming.nsf/content/ActionsWasteToolsRecon.html.
[5] Waste Reduction Model (WARM) website: http://yosemite.epa.gov/oar/globalwarming.nsf/content/ActionsWasteWARM.html.
[6] Energy Star® Calculator website: http://www.energystar.gov/index.cfm?c=bulk_purchasing.bus_purchasing.
[7] European Union RELIEF Project website: http://www.iclei-europe.org/?relief.

The EPEAT and FEC programs both have specifically defined criteria to be met. EPEAT criteria went through an American National Standards Institute (ANSI) public accreditation process resulting in an American National Standard: Institute of Electrical and Electronics Engineers (IEEE) 1680, "IEEE Standard for Environmental Assessment of Personal Computer Products including Laptop Personal Computers, Desktop Personal Computers, and Personal Computer Monitors" (IEEE Std 1680 – 2006.) EPEAT-registered products are designated at one of three levels – bronze, silver and gold. At the bronze level, EPEAT-registered products must meet all required EPEAT criteria, while silver- and gold-designated products are distinguished by the number of optional EPEAT criteria met.

All the EPEAT and FEC criteria selected for inclusion in the EEBC were those for which adequate data were available to quantify potential benefits. The environmental benefits of some EPEAT and FEC criteria are not easily measured (e.g., ease of product disassembly, corporate reporting criteria) or measurable at the time of product purchase (e.g., providing a product take back option). These criteria, for example, were not selected for inclusion in the EEBC. Table 1 presents the criteria that are included in the EEBC, Version 1.0.

TABLE I. EPEAT AND FEC CRITERIA SELECTED FOR INCLUSION IN THE EEBC TOOL

Criteria	Program Reference[a]
Purchasing: Reduced toxicity	
RoHS compliance (Pb, Hg, Cd, Cr6+, PBB, PBDE)	EPEAT 4.1.1.1
Hg in light source; maximum average of 3 mg Hg/lamp	EPEAT 4.1.3.1-2
Hg-free lamps	EPEAT 4.1.3.3
Purchasing: Material use	
Recycled content of product resin	EPEAT 4.2.1.1-3
Purchasing: Energy Conservation	
Energy Star® Compliant	EPEAT 4.5.1.1 – 2
Purchasing: Packaging	
Recycled content of packaging	EPEAT 4.8.3.1
Minimum 25% recycled content of corrugated packaging	EPEAT 4.8.3.2
Packaging avoided per unit by packaging reuse	EPEAT 5.8.5.1
Use	
Power management features enabled	FEC
Extend product life (longevity)	FEC
End of life	
Reused products	FEC
Recycled products	FEC

[a] EPEAT reference numbers correspond to those in IEEE Standard 1680 -2006.

Abbreviations: RoHS=Restriction on Hazardous Substances; Pb=lead; Hg=mercury; Cd=cadmium; Cr6+=hexavalent chromium; PBB= polybrominated biphenyl; PBDE=polybrominated diphenyl ether; EPEAT=Electronic Environmental Assessment Tool; FEC=Federal Electronics Challenge; IEEE=Institute of Electrical and Electronics Engineers.

D. Select Metrics

To meet EPA reporting needs, such as those required under the Program Assessment Rating Tool administered by the U.S. Office of Management and Budget, and to make the tool valuable for multiple users, the following metrics are included in Version 1.0 of the tool:

- Reduction in energy use;
- Reduction in primary virgin material use (e.g., increase in recycled materials);

- Reduction in greenhouse gas emissions;
- Reduction in total air emissions;
- Reduction in water emissions;
- Reduction in toxic materials use, including lead, cadmium, mercury and hexavalent chromium;
- Reduction in municipal solid waste generation;
- Reduction in hazardous waste generation; and
- Reduction in cost, where feasible.

Table 2 shows which environmental benefits will be calculated for each criterion.

The EEBC tool calculates environmental performance using these metrics, which are mostly "inventory metrics." Inventory metrics are generally direct measures of the quantities of materials, energy or cost and are commonly used in the United States to measure environmental benefit. One exception in the list above is the greenhouse gas emissions metric, which measures air emissions in terms of carbon equivalents. These carbon equivalents are derived using global warming potentials (GWP) of contributing air emissions. These GWPs translate releases of individual substances into impacts on global climate change. Thus, the metric measures the quantity of carbon equivalents, which measures potential impacts on global climate change, and thus would be considered an "impact metric." Future versions of the tool might consider more "impact metrics," which would translate inventory quantities into other environmental impacts. These are often final outputs of life-cycle analyses. For example, the inventory metric of mass of air emissions can also be translated to photochemical smog impacts, based on the photochemical oxidation creation potential (POCP) of specific contributing chemicals. The measurement priorities of EEBC tool users, including the EPA, as well as time and resource constraints, resulted in more inventory metrics and limited impact metrics included in the EEBC Version 1.0. Future modifications of the tool could incorporate these into the benefit calculations if they are a desired feature by the user community.

Some of the metrics listed above are the direct quantification of savings for a particular category, while others incorporate savings from more of the life cycle. For example, reduction in toxic materials quantifies only the amount of the particular toxic materials of concern (i.e., lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyl [PBB] and polybrominated diphenyl ether [PBDE]) in each product type.) On the other hand, other metrics incorporate more of the life cycle. The recycled content criterion, for example, includes not only the direct amount of materials saved from avoiding the manufacture of the virgin material, but also the savings of associated energy and greenhouse gas emissions.

The determination of which metrics to calculate for a given criterion was influenced by the availability of data and conversion factors needed for the benefits calculations. Future iterations of the tool could incorporate additional benefits calculations for individual criterion.

E. Define Baseline Product for Comparison

Calculations of benefits or savings require comparisons to baseline conditions. Data were collected from multiple sources on the typical attributes of the four products addressed in the tool: desktop computer unit, cathode ray tube (CRT) monitor, liquid crystal display (LCD) monitor, and notebook computer. The savings calculated for each metric are the differences between the baseline products and the amounts of each criterion for the products selected by the user. For example, a baseline product under EPEAT is assumed not to meet the European Union's Restriction on Hazardous Substances (RoHS). Thus, in the case of lead, the baseline desktop computer unit is assumed to contain lead-based solder, while EPEAT-registered products are assumed to be lead-free (i.e., zero or negligible lead concentrations.). Note, nominal lead levels allowed under RoHS are assumed to be negligible in the EEBC, given the

expected levels of precision in the calculations made in the tool. For EOL management, the baseline is assumed to be zero units reused or recycled.[8]

TABLE II. SAVINGS CALCULATED FOR EACH CRITERION

Criteria/Attributes	Metrics								
	Energy	Primary materials	GHG emiss.	Total air emiss.	Water emiss.	Toxics	MSW	Haz waste	Cost
	(kWh)	(kg)	(kg of CE)	(kg)	(kg)	(kg)	(kg)	(kg)	($)
PURCHASING									
Reduced Toxicity									
RoHS-Pb reduction						*		*	
RoHS-Hg[f] reduction (excludes lamps)						*		*	
Hg in light source; max avg of 3 mgHg/lamp						*			
Hg-free lamps						*		*	
RoHS-Cd reduction						*		*	
RoHS-Cr6+ reduction						*		*	
RoHS-PBB reduction						*		*	
RoHS-PBDE reduction						*		*	
Material Use									
Recycled content of product resin	*	*	*	*	*		*		*
Packaging									
Recycled content of packaging, corrugated	*	*	*	*	*		*		*
Recycled content of packaging, plastic/foam	*	*	*	*	*		*		*
Recycled content of packaging, other	*	*	*	*	*		*		*
Packaging avoided per unit by reuse	*	*	*	*	*		*		*
Energy Conservation									
Energy Star® compliant	*	*	*	*	*				*
USE									
% of units with power mgt features enabled	*	*	*	*	*				*
Extend life (longevity)	*	*	*	*	*	*	*	*	*
EOL									
Equipment reused	*	*	*	*	*	*	*	*	*
Equipment recycled	*	*	*	*	*	*	*	*	*

Abbreviations: GHG=greenhouse gas; MSW=municipal solid waste; Haz=hazardous; CE=carbon equivalents; RoHS=Restriction on Hazardous Substances; Pb=lead; Hg=mercury; Cd=cadmium; Cr6+=hexavalent chromium; PBB= polybrominated biphenyl; PBDE=polybrominated diphenyl ether

F. Advisory Committee and Peer Review

An Advisory Group guided the University of Tennessee team in the development of the tool. The Advisory Group, comprised of representatives from the U.S. EPA, state government, industry and not-for-profits, provided essential feedback on issues such as the scope of the tool, functionality, user interface and presentation of results. Upon completion, the EEBC was also subject to an extensive Peer Review Process, which focused on the baseline data

[8] Using a baseline value of "0" for recycling provides flexibility for multiple user groups. Anyone can use the calculator, regardless of whether they are calculating the benefit of recycling 10 or 10,000 computers. In addition, the calculator tool can measure the incremental benefit of recycling by plugging in the difference (# of units) between any defined baseline (e.g.,# of units recycled five years ago) and current or future recycling rates.

inputs, assumptions and benefits calculations. The Peer Review Group included representatives from industry, the U.S. EPA, and the federal government. A Peer Review Comment-Response Log was prepared and submitted to the U.S. EPA in a separate document. A list of Advisory and Peer Review Group members is provided in the Acknowledgements.

III. FINAL TOOL, VERSION 1.0

The EEBC tool, Version 1.0, consists of a Microsoft® Excel spreadsheet with seventeen worksheets within the overall workbook. The workbook was structured to include instructions and background information, user interfaces, a comparison sheet displaying data based on user-defined input alongside baseline data for each product type, displays of results (tables of calculated benefits, plus graphs and equivalents) and sheets displaying all supporting data and assumptions used in the benefits calculations.

A. User Interfaces

Sheets 1 and 2 include instructions and background for the user. Sheets 3a, 3b, and 3c are the user interfaces or data input sheets, which are user-friendly and incorporate Visual Basic programming. Sheet 3a requires minimum user input related to purchasing computer products. Sheet 3b is optional and asks for input on products in use and on EOL management. Sheet 3c is also optional and allows the user to customize data inputs on EPEAT-registered products rather than relying on default values.

For procurement, at the simplest level, a user inputs the type of system(s) purchased (e.g., desktop computer unit with an LCD), the number of units of each product purchased, and the level of EPEAT registration. When selecting the product types, the user can choose up to three products. Selections can be of the four different product types (i.e., desktop computer unit, CRT, LCD, and/or notebook) or they can be the same product type with different specifications. For purchases of a computer system consisting of a desktop unit and monitor, for example, these would be selected as two product types with the same number of purchases of each.

The basic analysis of EPEAT-registered products (Sheet 3a) relies on default assumptions for the distribution of which optional criteria are met for a given level of EPEAT registration (i.e., bronze, silver or gold). Based on these default assumptions and the number of products purchased, the tool generates results in terms of environmental benefits for each metric (e.g., energy saved, reduction in greenhouse gas emissions). Product registration data will be used to periodically update the default assumptions to reflect the mix of EPEAT-registered products available on the market. [9]

An alternative user input sheet for purchases (Sheet 3c) allows for customization of product attributes. EPEAT criteria are classified into mandatory and optional categories. The alternative purchasing input sheet allows the user to identify which specific optional criteria are met for the product they purchased, rather than rely on default values. For example, the user can select if the product uses mercury-free lamps, or specify the actual recycled content of the product resin. This enables users to customize data for a product, compare different product types, or compare similar product types that meet different criteria.

The purchasing criteria address both EPEAT and FEC criteria, as FEC has adopted the EPEAT criteria as its purchasing criteria. To address the remaining FEC criteria, which do not pertain to purchasing, Sheet 3b allows the user to define attributes of products in use and of obsolete products requiring EOL management. For the use life-cycle phase (i.e., operation and maintenance), the number of units in use, the percent power management features enabled, and the lifetime of the products in use are entered. For EOL management, data inputs include how many units are reused or recycled. These data are used to calculate savings for selected metrics as described earlier. A placeholder is available in Sheet 3b for the future calculation of the environmental benefit of recycling mixed office electronics by weight.

[9] The default values in the EEBC Version 1.0 were developed based on 71 product listings in the EPEAT product registry as of August 28, 2006. A review of the 251 products in the registry as of November 21, 2006 revealed that the default values remain as good assumptions.

Once the user inputs have been completed, the tool generates a summary of all data inputs and assumptions, which are subsequently used to calculate benefits. The summary (Sheet 4) presents data values for the user-selected products and presents them side-by-side with the pre-defined baseline data for each criterion.

B. Output

The results generated by the EEBC are presented in tabular and graphical formats. Sheet 5a presents the inventory metrics (i.e., benefits calculations) in tabular form, and Sheet 5b provides a written description of the calculations[10]. This is followed by Sheet 6, which presents summary graphs. Aggregate benefits for each inventory metric and product are calculated as well as the net cost and environmental savings for each EPEAT or FEC criterion. Detailed results by criterion allow the user to identify which criterion or product is contributing to which inventory metric. Results are also broken down by "decision point" life-cycle phases (i.e., purchasing, use, and EOL management)[11]. In addition to quantifying the inventory savings amounts, the EEBC translates the inventory metrics into common reference values or equivalencies (e.g., reduction in vehicle miles traveled) where appropriate. These are presented in Sheet 7.

The remaining sheets (8a, 8b, 8c, 8d, 8e, and 8f) present supporting data and assumptions that are used in the calculations. Data sources and relevant notes are also provided in these sheets. As these data are provided in this spreadsheet format, they can be easily modified for future versions of the EEBC and as additional data becomes available. The tool allows users to modify some assumptions, while other assumptions are in locked cells so that the values can only be changed by an EEBC system administrator.

Finally, the EEBC tool was also designed to have the flexibility of adding future functionality such as allowing for calculations for more than four products or incorporating impact metrics.

IV. CONCLUSIONS

The EEBC tool allows institutional purchasers and the federal government to quantify the environmental benefits of purchasing and improving the life-cycle management of computer products. The ability to easily calculate and demonstrate achievements will help justify procurement and recycling activities and strengthen programs by measuring results. The EEBC will be publicly released in early 2007. The tool structure allows for future upgrades and additions. It is expected that a simplified, web-based application of the EEBC will be available in the future.

Throughout the development of the EEBC tool, many ideas surfaced on what additional functions or aspects might be added to improve the tool. While often intrigued with the ideas, the project team had to focus on getting the basic EEBC up, running and de-bugged. With the delivery of the EEBC Version 1.0, the project team offers the following recommendations for future versions of the EEBC tool:

- Add the capability to calculate the benefits of biobased/renewable content (EPEAT criteria 4.2.2.2);
- Allow users to calculate the benefits of recycling mixed office equipment (by weight) in addition to per unit data entry;
- Modify summary graphs to represent the product life-cycle stages (i.e., manufacturing, use, and EOL) versus the decision point life-cycle phases as currently presented (i.e., purchasing, use, and EOL);
- Incorporate the ability to select specific graphical representations of results from a drop-down list, versus having several pre-defined graphs to scroll through.
- Incorporate additional life cycle aspects into the Calculator such as the value of precious metals and the upstream benefits of avoided mining;
- Incorporate life-cycle tradeoffs of expected or common alternatives to replace restricted materials (e.g., replacement solder for lead-free solder or replacement technology for mercury-free lamps;

[10] Appendix A provides a more detailed description of the calculations and is formatted to match Sheets 5a and 5b in the tool.
[11] The "decision point" life-cycle phases show calculated benefits at each decision point in the product's life, regardless of when the benefits occur in the life of the product. For example, benefits associated with a purchasing decision related to energy efficiency are presented as *purchasing* benefits, although the actual benefits may be realized during the *use* stage of the product. Further, the use phase benefits represent those from the use of currently operating products, not future purchases.

- Compare the benefits of different product types that perform the same function (e.g., CRT and LCD monitors) by expanding the product design considerations beyond EPEAT criteria[12];
- Expand the environmental benefits calculations to include additional impact categories (e.g., photochemical smog, eutrophication, acidification) in addition to the current impact measures;
- Expand the tool to include the recycle of additional electronics products (e.g., mobile telephones); and
- As EPEAT expands to include additional products, expand the tool to accommodate those products.

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[12] In Version 1.0 of the Calculator, different product types can be compared by selecting each in the user input sheets; however, care must be taken to incorporate any functional differences (e.g., if one technology is expected to last longer than the comparison technology, a factor can be applied to the number of products selected to account for a longer lifetime.

APPENDIX A

Description of calculations for the EEBC Tool v. 1.0

See Excel file: EEBCv1_0 Equations and calculations 12-29-06.xls

Note, this file has been formatted to be consistent with Sheets 5a and 5b of the tool.