Proposal Information Template for:
Battery Charger Systems

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2008 Appliance Efficiency Standards

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Purpose

This document is a report template to be used by researchers who are evaluating proposed changes to the California Energy Commission's (Commission) appliance efficiency regulations (Title 20, Cal. Code Regs, §§ 1601 – 1608). This report specifically covers battery charging systems (BEC).

Background

The function of many consumer electronic products depends on portable power to remain operative when disconnected from the AC wall outlet. Many portable products utilize rechargeable battery systems to supply portable power rather than rely on the availability of mains power. Electricity from the AC wall outlet is used to maintain various low power and trickle charge modes and to charge the battery itself. For the purpose of this report, the term "consumer battery charger" includes devices that are designed to run on battery power during part or all of their duty cycle. Battery chargers coupled with their batteries are together referred to as battery charger systems. This term covers all rechargeable batteries or devices incorporating a rechargeable battery, and the chargers used with them. The battery charging electrical contacts and charging circuitry may or may not be located within the housing of the appliance itself. Some products that are included in this definition (for example: cordless power tools) charge the battery with a dedicated charger and power supply combination that is separate from the appliance. For other products, like cellular telephones, the charging circuitry is typically located within the housing of the phone, with an external power supply to connect the charging circuitry to the AC outlet. This report includes both of these types of appliances, as well as those units that are sold solely for the purpose of charging rechargeable batteries. This includes batteries of a custom form factor as well as the familiar form factors: AAA, AA, C, D, and 9V. Not included in the definition of consumer battery charger are those battery service stations that are designed to maintain large fleets of batteries for commercial or industrial use, or battery analyzers that are intended for scientific and diagnostic testing.

Battery charger systems cover a broad range of consumer products and use several different charging technologies and battery chemistries. Because of the broad scope of products, there is significant energy savings potential in California.

Substantial interactions exist between the proposed battery charger standard and a related one for external power supplies. Some of the savings achievable with present battery chargers stem from improvements in their power supply efficiency.

Overview

Description of Standards Proposal	The proposed standard will have three components: Active, Standby, and Maintenance. Active mode considers battery energy: $$eff = \frac{E_{batt}}{E_{24}} \geq \frac{E_{batt}}{a + b * E_{batt}}$$ The standard could also be considered as an energy budget: $$E_{24} \leq a + b * E_{batt}$$ A two tier, staged standards approach, addresses first a near term standard to reduce the least efficient products, and second, an eventual standard for improved efficiency. The tentative schedule for Tier A requires an effective date of January 2010 and for Tier B, January 2011. The two-tier approach will allow time for manufacturers to change their design to meet the increasingly stringent standards. For specific information, see the Recommendations Section.
California Stock and Sales	The stock of battery charging products in California is currently estimated at 130 million units. The product categories with the largest stock numbers are home electronics, cell phones, cordless phones, and information appliances. The compound annual growth rate (CAGR) for sales varies significantly from one product to another, with some products growing at rates of over 100%. A small number of product categories are currently experiencing negative growth, due to competition with other more popular battery-powered products. For example, the sales CAGR for cordless phones is negative 9%, while for cell phones it is close to 17%. Similarly, portable CD players are at negative 20%, while mp3 players have a 79% CAGR. While categorical CAGRs could be calculated, an overall CAGR for BCSs would be inaccurate due to the large range of products.
Energy Savings and Demand Reduction	Energy delivered from BCS in California is estimated to be 400-700 GWh/year, while the actual energy used to charge these products is 3760 GWh/year. The two tiers of proposed standards could save 34% to 54% of the 3760 GWh/year. Tier A, with a savings of 34% could save California 1,278 GWh/year, while Tier B, with a savings of 54%, could save 2,030 GWh/year. The demand reduction ranges from 145,890 kW to 231,735 kW.
Economic	The incremental cost of improved charging technology is typically minimal

Analysis	to none. In many cases, inefficient products utilize similar charging components similar to highly efficient products, while achieving a drastically lower efficiency. Due to the reduced incremental cost or lack thereof, there should be a positive net-benefit to the consumer. Further cost benefit analysis will be conducted.
Non-Energy Benefits	Because many NiCd and NiMH batteries are overcharged, they are discarded long before their potential lifetime. A BCS standard would require smarter charging technologies, resulting in reduced battery overcharging, and therefore extending the life of certain batteries. For the consumer, the standard could result in fewer trips to the toxic collection center, fewer trips to the store for batteries, and decreased battery replacement cost. Consumers could also benefit from a reduction in toxic landfilled batteries, Currently, NiCd batteries present the most toxic health threat, even though they make up a large percentage of the rechargeable battery market. The EU banned cadmium for use in battery products in 2006, with some exemptions. China has also passed legislation banning cadmium in some products. The U.S. has no federal legislation restricting cadmium in battery products, but several states have unsuccessfully tried to ban the sale of it within their boundaries.
Environmental Impacts	This standard, if enacted, should not cause any adverse environmental impacts. The standard would result in improved California air quality, a reduction in global warming pollutants, and a similar reduction in other power plant emissions. These savings can be quantified in terms of power plants saved, carbon emissions avoided, and fewer cars on the road. With a 34% reduction in BCS energy, California could save 1,278 GWh/year, saving close to 1/2 a power plant, 677 million lbs of CO_2, and removing 100 cars from the road. With a 54% reduction in BCS energy, California could save 2,030 GWh/year, saving close to 2/3 power plant, 1.1 billion lbs of CO_2, and removing 162 cars from the road.
Acceptance Issues	Consumer acceptance issues are positive due to a “smart” charger’s product characteristics. More efficient chargers are typically lighter and lead to greater product portability for the consumer.
AB 1109 (California Lighting Efficiency and Toxics Reduction Act)	Not Applicable.
Federal Preemption or other Regulatory or	It is unclear currently how the recent passage of EISA 2007, the federal energy legislation, will impact a battery charger standard in CA. This legislation does not specifically address standards for those EPSs that accompany battery-powered products, and we therefore assume that existing CA Title 20 regulations on battery chargers will not face federal

Legislative Considerations	preemption. Additionally, EISA 2007 outlined a timetable for the U.S. DOE to evaluate and propose federal battery charger standards. A standards determination must be made by July 1, 2011, and any proposed standard would take effect three years later, in 2014. It is likely that the federal government would look to California and other jurisdictions in the interests of harmonization on test procedure and standards approaches.

Methodology
To fully develop an accurate BCS standard, the following steps were taken:

1. Developed a BCS Test Procedure including active, maintenance, and no battery mode
2. Tested a broad range of products, in the end totaling more than 250
3. Compiled data to analyze how BCSs utilize energy, how energy relates to battery chemistry and battery capacity, how energy relates to specific products, and how different charging technologies work
4. Conducted market research and developed product categories
5. Evaluated scope of tested products in order to better represent the California market
6. Conducted California energy analysis and developed staged standards based on energy savings
7. Finalized Recommendations for the BCS Test Procedure based on testing experience
8. Finalized recommendations for Standards Specifications

Analysis and Results
There is significant energy savings potential among BCSs. These products consume around 3,760 GWh of energy a year, which could be reduced by 34% initially, and up to 54% through the implementation of staged standards. If all products include a more efficient Level IV EPS, there would be an immediate 5% savings. Beyond this, larger changes in the charging circuitry are needed, presumably with little incremental cost to manufacturers since the costs of components used in efficient and inefficient chargers do not vary significantly.

Some of the largest energy savings potential exists in the following product categories: cordless phones, universal chargers, information technology, emergency backup battery systems, and cell phones. Large chargers used in products such as golf carts, electric vehicles, forklifts, etc., likely account for 30-40% of overall energy use, but they constitute a very small portion of the overall BCS units in California. Continued testing within the transportation product category should confirm these results.

Recommendations
We recommend adopting the Energy Efficient Battery Charger System Test Procedure developed by Ecos Consulting on behalf of Pacific Gas and Electric, with the modifications listed below. These modifications will be included in a version 1.1 to be posted on the website. We also recommend that the CEC issue a call for test data from manufacturers or other interested parties. Data received by March 15, 2008 can be used to help determine any modifications to the proposed standards that may be needed.

1. Section I, Scope, part B (Limitations), first paragraph, last sentence previously read: “The scope is also limited to battery charger systems whose complement of installed batteries has a total rated energy capacity of 50 kWh or less.” This should be changed to read: “The scope is also limited to battery charger systems whose battery has a rated energy capacity of 50 kWh or less. Battery chargers capable of charging batteries both less than and greater than 50 kWh shall be tested only with suitable batteries of 50 kWh or less.”

Reason: The old phrase “compliment of installed batteries” was misspelled, and could have been misinterpreted as referring collectively to all the batteries in use with a model of charger rather than as referring to all the batteries being charged simultaneously. The new wording avoids this possible ambiguity.

2. Add a new part G to Section V, Battery Charger System Setup Requirements to read:

G. Batteries with No Rated Charge Capacity.
If there is no rating for the battery charge capacity on the battery or in the instructions, then the technician shall determine a discharge current which meets the following requirements. The battery shall be fully charged and then discharged at this constant-current rate until it reaches the end-of-discharge voltage specified in Table D. The discharge time must be not less than 4 hours nor more than 5 hours. In addition, the discharge test (Section VI.F) (which may not be starting with a fully-charged battery) shall reach the end-of-discharge voltage within 5 hours. The same discharge current shall be used for both the preparations step (Section VI.B) and the discharge test (Section VI.F). The test report shall include the discharge current used and the resulting discharge times for both a fully-charged battery and for the discharge test.

For this section, the battery is considered as “fully charged” when either (a) it has been charged by the UUT until an indicator on the UUT shows that the charge is complete, or (b) it has been charged by a battery analyzer at a current not greater than the discharge current until the battery analyzer indicates that the battery is fully charged.

Note: When there is no capacity rating, a suitable discharge current must generally be determined by trial and error. Since the conditioning step does not require constant-current discharges, the trials may also be counted as battery conditioning. Further, the preparation step may be used as the proof that a discharge current is suitable, provided that the battery is “fully charged.”

Reason for the addition: About 30% of the products we have tested do not include a charge capacity rating for the battery. Determining the charge capacity of an unknown battery is not simple. In these cases, the technician must determine a discharge current to use. Our tests have shown that variations in the discharge current have only a small effect on the measured efficiency. This new section specifies how close the technician must be in order for the test results to be consistent and valid. Using discharge times less than 5 hours results in a slight underestimate of the efficiency. This removes the incentive that manufacturers might otherwise have to omit labels in the hope of gaining favorable treatment by the test procedure. Also, for batteries which do have a rated capacity, the average discharge time at 0.2C is 4.63 hours. This requirement will result in very similar times for unrated batteries.

Proposed Battery Charger System Efficiency Standards for the CEC:
We recommend that the CEC consider a two-tiered set of efficiency standards, with Tiers A and B to be adopted simultaneously for staged implementation as follows:

- Tier A would be a mandatory standard with enforcement to begin as soon as practical (9 months to 1 year after formal adoption by the CEC). It is intended to remove the least efficient products from the marketplace quickly.

- Tier B would be a mandatory standard with an effectiveness date approximately 12-15 months after the effectiveness date of Tier A. This efficiency level is readily achievable with cost-effective design features and could form the basis of voluntary labeling or utility incentive programs prior to its adoption as a mandatory standard.

The standards will apply to all ac-powered battery chargers included within the scope of the Energy-Efficient Battery Charger System Test Procedure. This includes all battery charger systems with a single-phase ac input power of less than 2 kW, with a few exceptions as detailed in the test procedure.

For the maintenance and no-battery power limits, recommendations are included for systems with a measured battery energy up to 300 Wh. This covers almost all portable and consumer household products. We are still investigating systems from 300 Wh to 50 kWh and expect to have recommendations by March 15, 2008. This range includes automotive/marine battery chargers and transportation equipment such as golf carts and forklifts – a set of products for which testing is more challenging and expensive. We expect that these chargers in these categories will be allowed higher power levels than the smaller chargers in the low power modes, but will also be expected to achieve higher charge mode efficiencies.

Battery chargers that can charge batteries of different capacities or voltages are required to be tested multiple times, as specified in the Test Procedure. These chargers are required to meet the efficiency and power specifications separately for each test. If the charger is tested at both 115 V 60 Hz and 230 V 50 Hz, only the tests performed at 115 V 60 Hz must meet the specifications.

The proposed requirements for Tier A are:

A1. The 24-hour charge-and-maintenance energy shall not exceed 36 Wh + 2.5 * Eb, where Eb is the measured battery energy capacity in watt-hours. This is equivalent to having an efficiency of at least:

$$\textit{Efficiency} \geq Eb / (36\ Wh + 2.5 * Eb)$$

A2. For systems with a measured battery energy up to 300 Wh, the maintenance power shall not exceed 1.5 W. We will propose a higher limit for larger capacity systems by March 15, 2008.

A3. For systems with a measured battery energy up to 300 Wh, the no-battery power shall not exceed 1.0 W. We will propose a higher limit for larger capacity systems by March 15, 2008.

The proposed requirements for Tier B are:

B1. The 24-hour charge-and-maintenance energy shall not exceed 12 Wh + 1.8 * Eb. This is equivalent to

$$Efficiency \geq Eb / (12\ Wh + 15 * Eb)$$

B2. For systems with a measured battery energy up to 300 Wh, the maintenance power shall not exceed 0.5 W. We will propose a higher limit for larger capacity systems by March 15, 2008.

B3. For systems with a measured battery energy up to 300 Wh, the no-battery power shall not exceed 0.3 W. We will propose a higher limit for larger capacity systems by March 15, 2008.

B4. If the peak ac input current exceeds 2 amps in charging, maintenance or no-battery mode, then the power factor shall be at least 0.50 in that mode.
Note: If not reported, the peak current can be calculated as

$$I_{peak} = (InputPower * CurrentCrestFactor) / (InputVoltage * PowerFactor)$$

B5. If the ac rms input current exceeds 5 amps in charging, maintenance, or no-battery mode, then the power factor shall be at least 0.85 in that mode.
Note: The rms input current can be calculated as:

$$I_{rms} = InputPower / (InputVoltage * PowerFactor)$$

Estimated Energy Savings
We estimate that about 130 million battery chargers in the state of California are within the scope of this standard, as of 2007. Base case energy consumption can be calculated one of two ways. The first base case presumes that most battery chargers sold in 2007 with an external power supply did not comply with California's EPS standards or complied only with Tier 1 (phased in between January and July of 2007). This leads to a base case energy consumption estimate of approximately 3,760 GWh/year of electricity. The second base case presumes that all battery chargers sold in 2007 with an EPS already complied with California's Tier 2 EPS standards (given the prevalence of ENERGY STAR products). This yields additional energy savings of about 5% and a base case value of 3,577 GWh/year. The

difference is small because most of the large battery charging systems employ internal power supplies.

Tier A products will average slightly lower energy use (about 5 to 6%) than the standards require, due to manufacturers' preference for leaving a margin of error between their design targets and legal requirements to account for manufacturing tolerances. Thus, we estimate that a Tier A standard would reduce energy consumption to 2,360 GWh/year -- a 37% reduction from the higher base case or a 34% reduction from the lower base case.

Similarly, we estimate that a complete stock turnover to Tier B-compliant battery chargers will reduce energy consumption to 1,630 GWh/yr. This represents a 56% reduction from the higher base case or a 54% reduction from the lower base case.

In summary, we would expect these standards to save California about 2,070 GWh/year, above and beyond what can be saved by the EPS standards alone.

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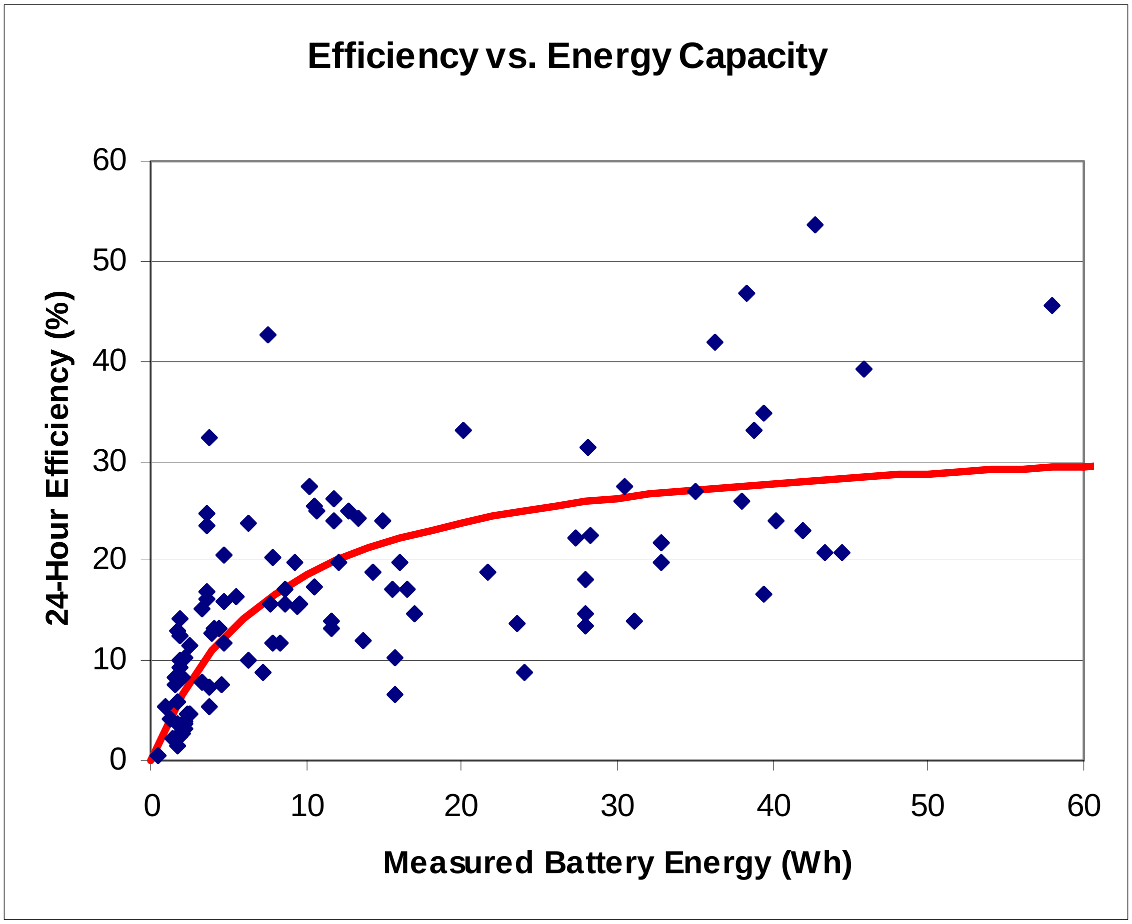
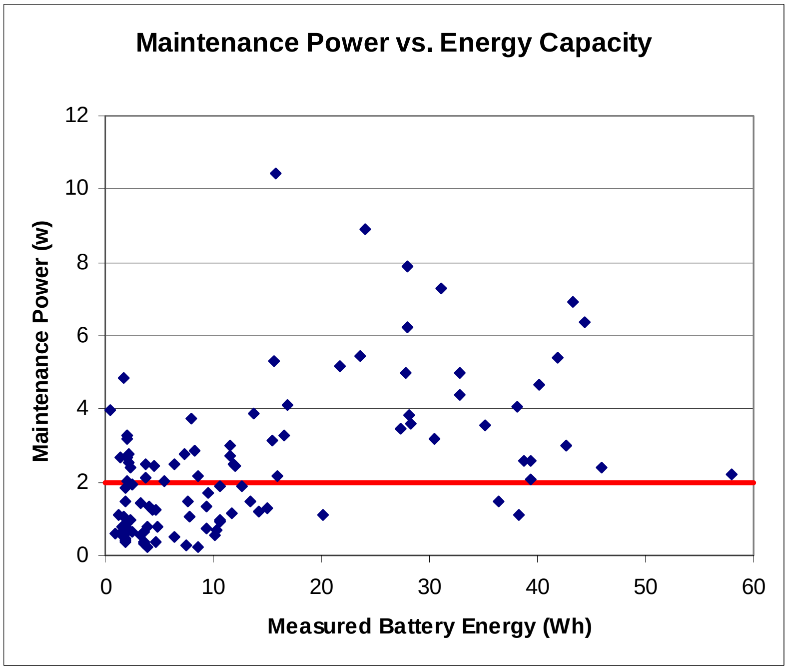
Appendices:




Maintenance Power vs. Energy Capacity
Maintenance Power (w)
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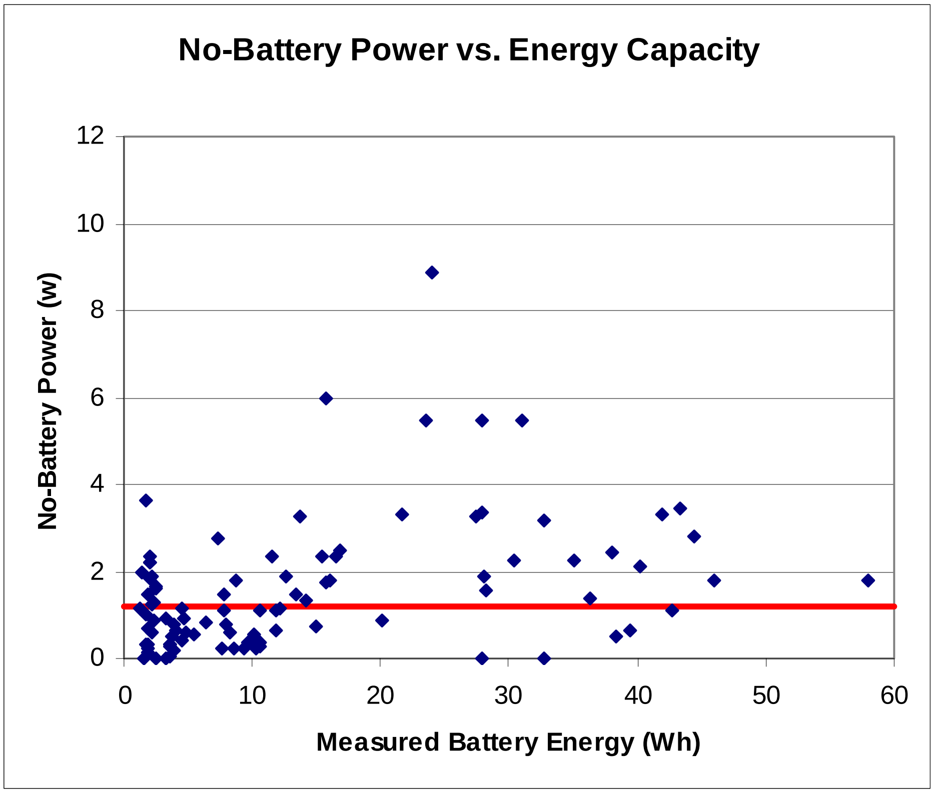
8
6
4
2
0
0
10
20
30
40
50
60
Measured Battery Energy (Wh)


No-Battery Power vs. Energy Capacity
No-Battery Power (w)
12
10
8
6
4
2
0
0
10
20
30
40
50
60
Measured Battery Energy (Wh)