CELLULAR PHONES

Advancements in Energy Efficiency and Opportunities for Energy Savings

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NRDC (Natural Resources Defense Council) is a national, nonprofit organization of scientists, lawyers and environmental specialists dedicated to protecting public health and the environment. Founded in 1970, NRDC has more than 1 million members and e-activists nationwide, served from offices in New York, Washington, Los Angeles and San Francisco. For more information, visit www.nrdc.org.

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EXECUTIVE SUMMARY

Worldwide sales of cell phones are approaching 500 million units per year. Given the sheer size of this market, the Natural Resources Defense Council (NRDC) retained Ecos Consulting (Ecos) to measure the energy consumption of cell phones and to assess the potential energy savings opportunity that might exist for this product category. No study to date has ever investigated the environmental impact of cell phone charging as it relates to national energy consumption and power plant greenhouse gas emissions.

In performing this research, we acquired and tested the battery charging systems of a variety of phones, including eight 2004 models and two pre-2003 models. The typical 2004 phone in our sample drew little–no load power and utilized lithium-ion (Li-Ion) batteries, efficient switch-mode power supplies, and efficient power management–during charging. The pre-2003 phones in the sample drew slightly more power in no load mode and used nickel-metal-hydride (Ni-MH) batteries, linear power supplies, and minimal power management during charging. The following values were measured during testing:

- Power used to charge battery over a five-hour period. (In most cases, the phone finished charging the battery in the first three hours of the test. The remaining two hours the phone was in a low power "maintenance mode.")
- Power consumed in "no load" mode, when external power supply is plugged into the wall socket with no phone attached.
- Active mode efficiency of the external power supply provided with the phone.

Our measurements revealed the following:

- On average, cell phones consume roughly 3 to 6 watts during the majority of their charge cycle.
- Most 2004 cell phones drop into a low-power mode (less than 1.5 watts), and sometimes no–power mode (0 watts) once the battery has completely charged. The two pre-2003 models tested continue to draw a relatively constant level of power even after the battery has been charged, and consume about 3 watts from the wall outlet until the phone is unplugged from the external power supply.
- On average, 2004 cell phone power supplies use 0.2 watts when the charger is left in the socket and the phone is no longer attached. Some phones consumed up to 1 watt, while the best designs drew essentially no power when the phone was disconnected.
- The average efficiency of current cell phone power supplies ranged from 46 percent to 74 percent and the average efficiency was 68 percent.

Below is a table of the key findings from our research based on the above power measurements and an assumed duty cycle[1]:

Cell Phone Vintage	Average PS Efficiency	Daily Energy Use (Wh/day)	Annual Power Use (kWh/yr)
2004: Li-Ion battery, switch mode power supply, efficient power management	68%	17	6.1
Pre 2003: Ni-MH battery, linear power supply, minimal power management	52%	42	15

Much to our surprise the average electricity consumption of 2004 cell phones charged 12 hours each night is only 6 kWh per year, which translates to roughly 50 cents in annual energy bills. To put this in perspective, this is roughly the same amount of energy that would be needed over the course of a year if someone wanted to run a 60-watt light bulb for 15 minutes every day.

Based on our estimates, it appears that the energy consumed by cell phone charging has been reduced by at least 50 percent in the past two years due to two technological shifts in the marketplace: a) increased utilization of power management and low-power modes in the cell phone battery charging process, and b) use of smaller, more efficient switch-mode power supplies in lieu of bulkier and less efficient linear power supplies.

NRDC and Ecos identified three remaining energy savings opportunities in cell phones: 1) shifting to higher efficiency switch-mode power supplies that are roughly 75 percent efficient in active mode, 2) improving the power management during the charge sequence, effectively lowering power consumption in maintenance mode from the current average of 0.5 watts to 0.3 watts, and 3) lowering power consumption in no-load mode from the current average of 0.2 watts to 0.1 watts.

Assuming that all of the phones in the current U.S. subscriber base incorporated these three energy-saving measures, the country could save about 300 million kWh in electricity per year. This amounts to $22 million in electric utility costs, or 216,000 short tons of CO_2 emissions from power plants.

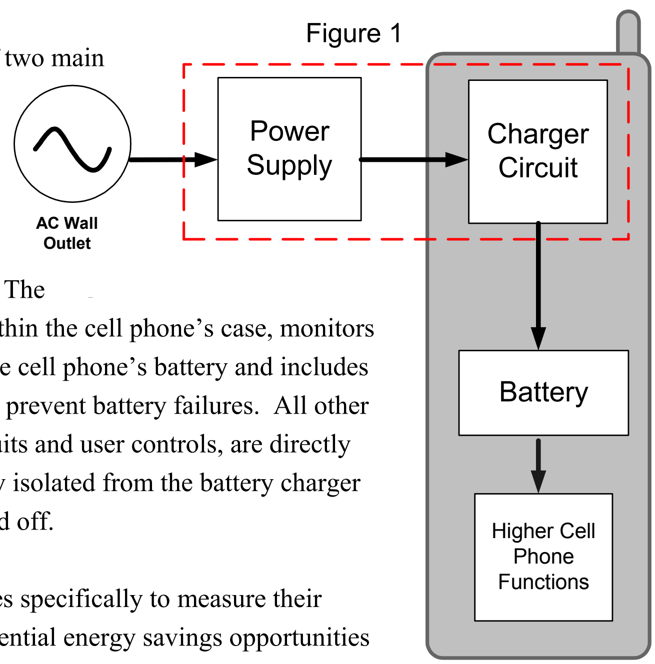
While these savings estimates might seem impressive in total, the per-phone savings are relatively miniscule, with the incremental electricity savings amounting to only pennies per year. As such, it would likely be difficult to persuade policy makers to devote resources toward measures that would further promote a market transformation in this direction. In addition, recent policy developments around labeling and regulating external power supply efficiency through the ENERGY STAR® program and California Energy Commission (CEC) regulations will help to transform the cell phone marketplace without any further intervention or cell-phone-specific policy measures.

Cellular phones, the largest component of the portable devices market, have experienced explosive worldwide growth in the past few years, with worldwide annual sales figures approaching 500 million units and growth in shipments around 11 percent.[2] Asia has the world's largest cell phone market, with 300 million subscribers in China alone,[3] and the United States remains one of the world's largest cellular phone markets with approximately 160 million subscribers.[4]

Manufacturers are introducing phones with ever-increasing functionality. So-called "convergence devices" such as "smartphones," web browser phones, digital camera phones and MP3 player phones, are now common in the marketplace. The development of third-generation (3G) cell phone networks is enabling fast data transfer rates up to 2 Megabits per second,[5] expanding the utility of a cell phone into new areas such as music downloads, photo e-mail, and streaming video. This convergence of other digital applications into cell phones, coupled with increased data transfer rates, means that cellular phones will continue to require more power to perform their expected tasks.

Because cell phones have a variety of dynamic user functions, such as screen brightness, data transfer capabilities, etc., that vary from phone to phone, it would be an extremely difficult and complex task to consistently measure the efficiency of an entire cell phone while it is in operation. Additionally, because users are demanding more talk time from the phones, there is already great pressure on Original Equipment Manufacturers to optimize the energy efficiency of the electronics in the phone that drive these higher user functions. For these reasons, Ecos' 2004 research for NRDC focused on the "common denominator" of every cell phone: the battery charging system.

Figure 1



The battery charger system consists of two main components contained within the dotted line in Figure 1: the power supply and the battery charger circuit. The power supply converts high-voltage AC electricity to low-voltage DC electricity and resides outside the case of the phone. The battery charger circuit, usually housed within the cell phone's case, monitors and controls the flow of electricity into the cell phone's battery and includes safety and power management features to prevent battery failures. All other higher functions, such as transmitter circuits and user controls, are directly powered by the battery and are effectively isolated from the battery charger system itself when the cell phone is turned off.

NRDC has decided to study cell phones specifically to measure their energy consumption and to assess the potential energy savings opportunities that might exist for this product category. To date, no prior study had ever looked into the overall energy use of cell phones. We have found that the cell phone market has shifted toward more energy-efficient battery charging technologies in the past several years. Today's cell phones almost exclusively incorporate switch-mode power supplies and efficient power management schemes, which has significantly reduced their overall energy consumption to around 6 kWh per year per phone.

Our 2004 report attempts to answer the following questions:

- How much energy is consumed to charge today's cell phones, and how does this compare to the phones of just a few years ago?
- What are some of the opportunities for additional energy savings in today's cell phones?
- How much energy could be saved by implementing these energy-saving design changes in cell phones? Similarly, how many CO2 emissions from power plants could be prevented?

Units Tested and Test Procedure Summary

Ecos conducted energy efficiency testing on eight currently available cell phones and two pre-2003 cell phones to assess the power consumption and overall energy efficiency of a range of cell phone battery charging systems. (See Appendix A for a complete listing of products tested.) The testing focused on measuring the efficiency of the battery charging system that is responsible for converting AC electricity from the wall plug into extractable DC electricity from the cell phone battery. As a result, the scope of the test procedure used by Ecos did not cover the AC-DC efficiency of the various subsystems powered by the battery (LCD screens, microprocessors, etc.).[6]

To eventually estimate the energy consumed by cell phone chargers, we first measured the power consumption of the cell phone battery charger system while charging the battery and maintaining full charge (charge and maintenance mode, respectively) as well as the energy extractable from the cell phone's battery once fully charged. In addition, the no-load (standby) mode power consumption and active mode efficiency of the cell phone's external power supply were measured.[7] While no formal cell phone test procedure exists, our methodology was derived from a general battery charger appliance test procedure, which Ecos helped to develop, that was modified in 2004 in response to industry comments on the draft that were received in 2003.[8] The basic tests (with the cell phone "off" in every case) are summarized in Table 1 below.

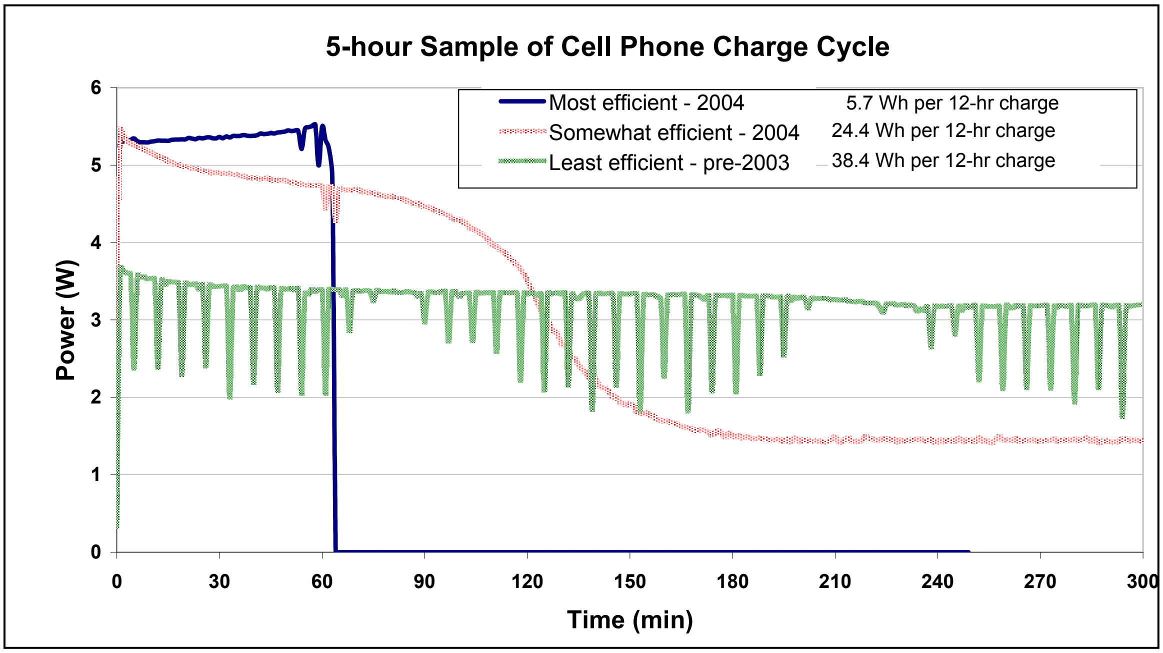
Table 1: Cell Phone Charger System Efficiency Tests

Battery Charge and Maintenance Test	The instantaneous power use and total energy consumption of the cell phone charger system is measured while the cell phone charges over a five-hour period. For part of this test, the charger system may be in battery maintenance mode.
Battery Discharge	The total energy extractable from a fully charged cell phone battery is measured with a battery analyzer while the battery is discharging at a constant rate.
No Load/Standby	The average power consumption of a cell phone power supply (with no cell phone attached) is measured over a five-minute period.
Active-mode Power Supply Efficiency	The active mode efficiency of a cell phone power supply is measured at 25percent, 50 percent, 75 percent and 100 percent of the nameplate current as per the international external power supply test procedure.

Results of 2004 NRDC Testing

Figure 2 shows the various power management schemes of cell phones during the five-hour charge/maintenance test period. Note that the 2004 phones drop into a low-power or sometimes no-power mode once the battery has completely charged (consuming an average of 14 Wh over a 12-hour charge), whereas the pre-2003 phone continues to draw a relatively constant level of power after the battery has been fully charged (consuming roughly 38 Wh over a 12-hour charge). Because there is no power management functionality to enable the charger system to go into a low-power mode, the pre-2003 battery charging system consumes 2.7 times as much energy as most of the current battery charger systems during a typical 12-hour charge period.

Figure 2



Not only are there marked differences between the power management schemes of new and old phones, but also the older power supplies are less efficient compared to current cell phone power supplies. Table 2 below summarizes the results of cell phone power supply testing using ENERGY STAR® external power supply specification as grounds for comparison. These stark differences in power management – shown in Figure 1 – and power supply efficiency – shown in Table 2 – confirm that the cell phone market has indeed shifted toward more efficient technologies since the original 2002 scoping study.

Table 2: ENERGY STAR® External Power Supply Comparisons

Cell Phone Vintage	Average No-Load Power Use (W)	Average Active Mode Efficiency	Percent of Units Passing Draft 3 ENERGY STAR® External Power Supply Specification
2004 (n=15)	0.246	62%	67%
Pre-2003 (n=2)	0.326	52%	0%

Energy is also consumed by the cell phone's power supply in no-load mode. Recall that no load means that the cell phone's power supply is plugged into a wall outlet, but the phone itself is disconnected from the power supply. On average, 2004 phones consume about 0.2 watts in no-load mode. However, we have observed some phones that consume *no* power in this mode, presenting an additional opportunity for energy savings.

Energy Consumption Estimates

The test data gathered in the lab from each phone was combined with duty cycle assumptions in order to develop estimates for the total kWh of AC electricity consumed by a cell phone on an annual basis. Unfortunately, information on consumer battery charging habits (how many times a user charges the phone per week, how many hours the phone is plugged in after the charge is complete, etc.) does not exist.[9] As a result, our calculations incorporate assumptions that are based on Andrew McAllister's preliminary research on the patterns of cell phone users, but they do not reflect a wide survey of users.

For this research, we assumed that the average cell phone user charges their phone once per day. The cell phone charger system spends a total of 12 hours per day in charge (actively charging the battery) and maintenance (low-power mode after the battery is fully charged) modes combined, which is a reasonable approximation of the amount of time that a phone might spend plugged in if the user intended to charge it overnight. A contemporary, 2004 battery charger system will complete its charge cycle during the first three hours of this 12-hour period and then drop to a low-power maintenance mode, while all pre-2003 systems we have examined will continue to consume a fairly constant amount of power even when the battery has been fully charged.

We assume that the cell phone is unplugged from its power supply for the remaining half of the day, and the power supply remains plugged into a wall outlet. The power supply, thus, remains in no-load mode (also called "standby" or "no battery") for 12 hours a day. Our duty cycle assumptions are summarized in Table 3 below. We recognize that these assumptions reflect somewhat of a worst-case scenario, and these can be modified to reflect new data as it becomes available.

Table 3: Duty Cycle Assumptions

Mode of Operation	Duration
Charge and Maintenance Modes	12 hrs/day
No Load (Standby)	12 hrs/day
Power Supply Unplugged from AC Wall Outlet	0 hrs/day

Based on our assumed duty cycle, we estimate that current cell phones can consume anywhere from 2 to 13 kWh per year. This translates into $0.14 to $0.90 in annual electricity costs to operate a cell phone, assuming an average electricity rate of $0.07 per kWh. We were surprised by the relatively low annual energy consumption of current cell phones, especially in comparison to older phones that employed low-efficiency linear power supplies and minimal power management during the charge cycle. Based on our calculations, these older designs would use approximately 15 kWh of electricity annually or about 9 kWh more than the typical cell phone in 2004. Table 4 below summarizes our findings on the annual energy use of cell phones.

Table 4: Annual Energy Use and Costs of Cell Phones

Cell Phone Vintage	Average Annual Energy Use (kWh per year)	Average Energy Cost (USD per year)
2004: Li-Ion battery , switch-mode power supply, efficient power management	6.1	$0.43
Pre-2003: Ni-MH battery, linear power supply, minimal power management	15	$1.05

Energy Savings Estimates

Recall that the three major opportunities for energy efficiency improvements in cell phones outlined above are: a) the effectiveness of the power management scheme employed, b) the active mode efficiency of the phone's external power supply, and c) the no load power of the external power supply.

To improve the active mode efficiency of the cell phone's external power supply, a manufacturer could implement high-efficiency switch-mode power supplies. Although the majority of the samples we tested employed the more efficient switch-mode power supplies (6 of 8 units), the least efficient phones on the market still use linear power supplies (2 of 8 units).[10] As a result, the energy consumption of these less efficient phones is similar to the pre-2003 designs that we measured, with UEC's approaching 13 kWh per year. Phones utilizing switch-mode power supplies, on the other hand, are estimated to consume less than 6 kWh per year. We estimate that the average cell phone today can achieve 62 percent efficiency in the active mode; however, we know from our measurements that efficiencies approaching 75 percent are achievable. If all U.S. cell phones implemented the most efficient switch-mode power supply that we measured (active mode efficiency of 74 percent), this measure could save 120 million kWh of electricity every year, amounting to $8.4 million in electric utility costs, and eliminate 84,000 short tons of CO_2 emissions from power plants.

Another opportunity for energy savings in current phones would be to incorporate highly efficient, switch-mode battery charger circuits in cell phones. However, according to an industry expert, most cell phone manufacturers utilize lower efficiency linear battery charger circuits in cell phones as a way to reduce cost, and it is unlikely that there would be compelling economic motivation to install more efficient and expensive switch-mode charger circuits.[11]

A more realistic way for manufacturers to reduce energy consumption in the battery charger circuit would be to implement better power management schemes that draw less power in maintenance mode. Pre-2003 cell phones that we tested continued to consume roughly 3 watts even after the battery is fully charged. As mentioned, current cell phones tend to drop into a low-power state that is comparable to no-load mode. The average maintenance mode power in current phones is about 0.5 watts, but 0.3 watts is technically achievable based on our measurements. If all cell phones in the United States were more efficient in their power management and dropped to 0.3 watts in maintenance mode, we estimate that the United States could save 87 million kWh of electricity every year. This amounts to about $6 million in electric utility costs, and avoids 61,000 short tons of CO_2 emissions from power plants.

Finally, the third opportunity for energy savings in current cell phones would be to decrease power consumed by the cell phone's external power supply in no-load mode. The average cell phone today consumes about 0.2 watts under no load; however, combined results from Cadmus Group and Ecos on cell phone external power supplies suggest that 0.1 watts is easily achievable. If all phones in the United States were to consume 0.1 watts under no load, the country could save about 101 million kWh of electricity every year. This amounts to $7 million in electric utility costs, and avoid 71,000 short tons of CO_2 emissions from power plants.

If all three of the above measures – highly efficient switch-mode power supplies, efficient power management, and low no-load power – were all implemented simultaneously through a market transformation program and labeling program such as ENERGY STAR ®, we estimate that the United States could save about 300 million kWh of electricity every year, assuming that the program achieved *100* *percent market penetration.*[12] This would be the equivalent of $22 million in electric utility costs, or 216,000 short tons of CO_2 emissions from power plants.

Table 5: Energy Savings Estimates for 2004 Cell Phones

Savings Opportunity	Energy Saved (Millions kWh)	Dollars Saved (Millions USD)	CO_2 Saved (Thousand Short Tons)
High-efficiency switch-mode power supplies	120	8.4	84
0.3 W maintenance mode power	87	6.1	61
0.1W no load power	101	7.1	71
ALL MEASURES	308	21.6	216

In the case that such measures were unable to achieve 100 percent market penetration, Table 5 below shows how the total combined savings might break down on an annual basis with reduced levels of market penetration.

Table 6: Annual Energy Savings Estimates for Current Cell Phones

% Market Penetration	Energy Saved (Millions kWh)	Dollars Saved (Millions USD)	CO_2 Saved (Thousand Short Tons)
100%	308	21.6	216
50%	154	10.8	108
25%	77	5.4	54

Although the aggregate savings may be impressive, the per-unit lifetime savings – the energy savings that a cell phone subscriber would see over the 18-month average lifetime of the product – would only amount to approximately 3 kWh, or about $0.26, or less than a dollar over the life of the phone.

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK

Technical Findings

Our measurements suggest that the cell phone market has made a dramatic shift toward more energy-efficient designs in the past two years; the average annual energy use of cell phones has decreased by more than 50 percent since NRDC and Ecos first examined battery charging products. Most cell phones currently employ switch-mode power supplies with low no-load and, in some cases, efficient power management schemes that only draw current from AC wall outlets when charging the cell phone battery. We have determined that cell phones are inherently low-power devices with low annual energy use. Even the energy consumption of today's least efficient cell phones pale in comparison to the energy consumption of larger electronic devices such as laptops, TVs, and computer monitors. To put this in perspective, today's average cell phone consumes 50 to 80 times *less* energy per year than a typical TV set.

Policy Recommendations

A relatively small amount of estimated energy savings per cell phone unit is achievable through improved power supplies, more efficient power management, and reduced no-load power. This energy savings amounts to less than a dollar per year on a consumer's electric utility bill.

Because of the low estimated dollar savings and the relatively short product lifetime of cell phones (typically only 18 months), it would make little sense to target this product category with utility-offered incentives or mandatory standards. The pending ENERGY STAR® specification and the California Energy Commission's upcoming mandatory standard for external power supplies are likely to provide enough market influence to encourage the least efficient cell phone chargers that are currently sold with linear power supplies to incorporate switch-mode power supplies that are found in the more efficient cell phone charger systems.

Although outside the scope of this report, a significant and potentially much larger environmental issue compared to the energy consumption of cell phones is the solid waste resulting from cell phone disposal. It is estimated that 65,000 tons of cell phones are being discarded by Americans every year[13], adding to the rising tide of so-called "e-waste" or electronic waste. We estimate that cell phones comprise about 3 percent of all e-waste in the United States.[14] This trend is compounded by the fact that the average cell phone lifetime is very short (less than two years), and thus, consumers replace their cell phones and accompanying power supplies on a more rapid basis than they might replace, say, a computer or television.

Recommendations for Future Work

Although this research did not focus on portable products other than cell phones, NRDC and Ecos did reaffirm over the course of this research that, in general, battery charger systems that employ switch-mode power supplies and efficient power management schemes are more efficient than typically less expensive battery charger systems that typically use linear power supplies and may disregard power management altogether. (For a brief explanation behind this design choice, please refer to Appendix C) These less expensive, commodity devices include cordless power tools, portable cordless phones, stand-alone battery chargers, cordless vacuums, etc. The lack of power management in these devices can dramatically increase the overall energy use of the product and potentially reduce the life of the battery. Although NRDC and Ecos determined that current cell phones should not be addressed with individual product specifications and standards, this does not preclude the possibility of energy savings specification and standards opportunities directed toward less expensive battery charging products that typically do not employ the power management schemes that we see in most of today's cell phones.

We suggest that future battery charger work take a wider approach and examine Ni-Cd, Ni-MH, and lead-acid battery charger systems that are used in commodity consumer products like cordless tools and portable telephones. There seems to be a potential for large energy savings by encouraging these manufacturers to incorporate efficient power management and switch-mode power supplies similar to those employed in the 2004 cell phones.

The low annual energy use of cellular phones is encouraging in that it may warrant future research comparing the energy use of cell phones to that of other telephony equipment. "Land-based" telephone equipment – cordless phones, answering machines, and combination phone systems that cell phones can effectively replace – can use up to three times the amount of energy per year when compared to cell phones, according to a 1999 Lawrence-Berkeley National Laboratory report.[15] Unfortunately, little is known about the energy efficiency of the entire cellular phone transmission infrastructure including base stations and indoor signal boosters. Further research into the system-wide efficiency of cell phones versus land-based telephone equipment would be required to inform any policy recommendations that might encourage low-power cell phones over land-based telephone hardware.

APPENDIX A

Table of Cell Phones Tested by Ecos Consulting for 2004 NRDC Research

Manufacturer	Model	Phone Vintage	Battery Chemistry	Typical Power Use (W)	Estimated UEC (kWh/year)	Power Supply Type	Active Mode Power Supply Efficiency
Ericsson	6160	pre-2003	used Ni-MH	*Charge*: 3.2 *Maintenance*: 3.2 *No load*: 0.33	15	linear	52%
Kyocera	3250	2004	new Li-Ion	*Charge*: 4.5 *Maintenance*: 1.4 *No load*: 0.90	13	linear	46%
LG	LX5450	2004	new Li-Ion	*Charge*: 4.5 *Maintenance*: 0 *No load*: 0	3.4	switching	74%
Motorola	T720C (2 units)	2004	used Li-Ion	*Charge*: 2.8 *Maintenance*: 0.83 *No load*: 0	5.5	switching	64%
Nokia	3587i	2004	new Li-Ion	*Charge*: 3.7 *Maintenance*: 0.36 *No load*: 0.33	8.2	linear	49%
Nokia	3588i	2004	new Li-Ion	*Charge*: 5.5 *Maintenance*: 0 *No load*: 0	2.1	switching	69%
Nokia	5185i	pre-2003	used Ni-MH	*Charge*: 3.2 *Maintenance*: 3.2 *No load*: 0.31	15	linear	52%

APPENDIX B

Cell Phone Power Supplies Tested by Cadmus Group for 2004 EPA Research

Manufacturer	Phone Model	Power Supply Type	Active Mode Power Supply Efficiency	No Load Power (W)
Motorola	i205	switching	62%	0.30
Motorola	V60	switching	52%	0.15
Nokia	3595	linear	51%	0.37
Samsung	A310	switching	59%	0.17
Siemens	S56	switching	55%	0.42
Sony-Ericsson	T610	switching	69%	0.12

APPENDIX C

Design Choices for Different Battery Chemistries

One of the main reasons that today's cell phones incorporate switch-mode power supplies as opposed to older linear power supplies is that prices on switch-mode power supplies have dropped. Furthermore, switch-mode power supplies are more compact and portable than linear power supplies.

Efficient power management is more prevalent in today's phones not because cell phone manufacturers intend to increase the efficiency of their product, but because Li-Ion batteries can rupture or combust if overcharged. Overcharging Li-Ion batteries is simply not an option due to safety concerns, and manufacturers must limit their liability by incorporating battery monitoring and power management features that ensure the battery is properly treated.

Although overcharging a Ni-Cd, Ni-MH, or lead-acid battery may shorten the battery's life and is certainly not recommended by battery cell manufacturers, it does not pose the same immediate safety risks to the consumer. For this reason, many battery chargers designed for these chemistries do not incorporate battery monitoring and power management to the same degree as Li-Ion systems, where safety is a foremost concern. As a result, these systems are typically less efficient than comparable Li-Ion systems at least based on the preliminary observations that we have made comparing 2004 cell phones (Li-Ion systems) with pre-2003 systems (Ni-MH systems). Cost is the main reason that more advanced power management and battery monitoring functionality have not been as widely incorporated into battery chemistries other than Li-Ion in commodity applications; however, we foresee no technical hurdles toward the implementation of these energy-saving features.

Endnotes

[1]For this research we assumed that the cell phone battery was charged each night and that the power supply was not unplugged from the wall socket after the phone was removed. We assumed 12 hours per day for the charge and maintenance mode and 12 hours per day for no-load condition.

[2] In-Stat/MDR, "Riding the Growth Curve: Annual Mobile Handset Forecast," July 2004. Report details available at www.instat.com/press.asp?Sku=IN0401700WH&ID=1031.

[3] Cellular Online, "Record sign-ups lift China mobile income," May 2004. Report details available at www.cellular.co.za/news_2004/may/050404-china-record_sign.htm.

[4] ICF Consulting, "Mobile Phone Market and Industry Research Report." March 2004. pp. 14-15

[5] ICF Consulting. pp. 1-3.

[6] All of Ecos' battery charger efficiency tests were performed with the cell phone turned off so that *only* the battery charging functions of the units were enabled during the test.

[7] Calwell, C., Foster, S., Reeder, T. and Mansoor, A., "Test Method for Calculating the Energy Efficiency of Single-Voltage External AC-DC and AC-AC Power Supplies," August 2004.

[8] For more detailed information on testing, please consult the following documents available at www.efficientpowersupplies.org.

Foster, S., Calwell, C., McAllister, A. and Mansoor, A., "Proposed Test Protocol for Measuring the Energy Efficiency of Battery Charging Appliances," October 2003.

Foster ,S., Calwell, C., Reeder, T. and Neugebauer, R., "Battery Chargers and Energy Efficiency: Summary of Findings and Recommendations," Natural Resources Defense Council, August 2003.

[9] Personal communication with Andrew McAllister, UC Berkeley Energy and Resources Group, August 2004.

[10] When data reported to Ecos by Cadmus Group is included, only 3 out of the 15 collective cell phones examined by Ecos and Cadmus utilize a linear power supply.

[11] Personal communication with Berndt Krafthoefer, product manager for Power Management, Texas Instruments at 2004 Portable Power Conference. September 14, 2004.

[12] This assumes the entire stock of cell phones in the United States today were replaced with more efficient cell phones.

[13] Fishbein, B., "Waste in the Wireless World: The Challenge of Cell Phones," *Inform*, May 2002. www.informinc.org/wirelesswaste.php.

[14] "Solving the Problem of Electronic Waste (e-waste)," U.S. Environmental Protection Agency, July 29, 2004,. www.epa.gov/epaoswer/osw/conserve/clusters/ecycle.htm.

[15] Rosen, K., and Meier, A., p. 4.