The Energy Efficiency of Common Household Battery Charging Systems: Results and Implications

Suzanne Foster

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ecos CONSULTING

On behalf of the Natural Resources Defense Council (NRDC)

Background on NRDC

- Leading environmental group with extensive energy efficiency expertise
- Interested in reducing emissions from power plants (reducing global warming)
- Prefers to collaborate with industry to develop “win/win” solutions
- Recent work - improving the efficiency of soda machines, computer monitors and ceiling fans

Background on Ecos Consulting

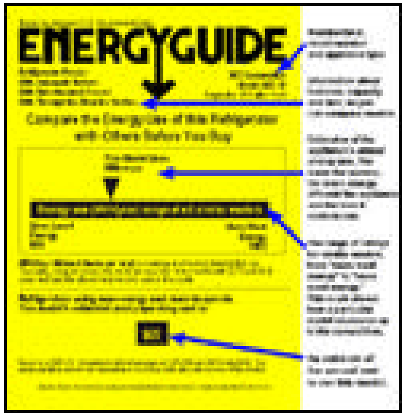
- Works primarily for electric utilities, government agencies, & non-profit organizations
- Conducts technical & market research & implements retail-based programs to increase sales of energy efficient products
- Strongest focus on residential lighting, consumer electronics, & office equipment
- Offices in Oregon, California & Colorado

Overview

- Energy efficiency basics
- National context
- Standby efficiency results
- Active efficiency results: AA, cellular phone, laptop computers
- Implications: Where do we go from here?

Energy Efficiency

- **Consumption** and generation
- Energy Efficiency = useful performance / energy consumed
- EPA’s Energy Star & DOE’s Energy Guide Label



Household Battery Charging Systems

www.batteryuniversity.com

Why Focus on the Efficiency of Battery Chargers?

- Simple solutions are possible
- Estimated 500 million residential battery charging systems
- System efficiencies are very low – often 30% or less, so the savings potential is significant

Energy Efficiency: Modes of Operation

	Time	Power	Definition
Off	*Large Value*	*Small Value*	*Charger plugged in but no batteries*
Standby	*Large Value*	*Small Value*	*Charger plugged in with fully charged batteries*
Active	Small Value	Large Value	Charger plugged in and charging batteries

the White House
President George W. Bush

Executive Order

- Sets standby power to 1 watt

  "Each agency, when it purchases commercially available, off-the-shelf products that use external standby power devices, or that contain an internal standby power function, shall purchase products that use no more than one watt in their standby power consuming mode."

- Requires a product database

  "*By December 31, 2001, and on an annual basis thereafter, the Department of Energy, in consultation with the Department of Defense and the General Services Administration, shall compile a preliminary list of products to be subject to these requirements.*"

July 30, 2001

ENERGY STAR Spec: Answering Machines and Cordless Phones

- Answering Machines & Cordless Telephones
  - Consume 3.3 watts or less when inactive. Models with spread spectrum technology may qualify at 3.6 watts or less.
- Combination Cordless Telephones/Answering Machines
  - Consume 4 watts or less when inactive. Models with spread spectrum technology may qualify at 5.1 watts or less.

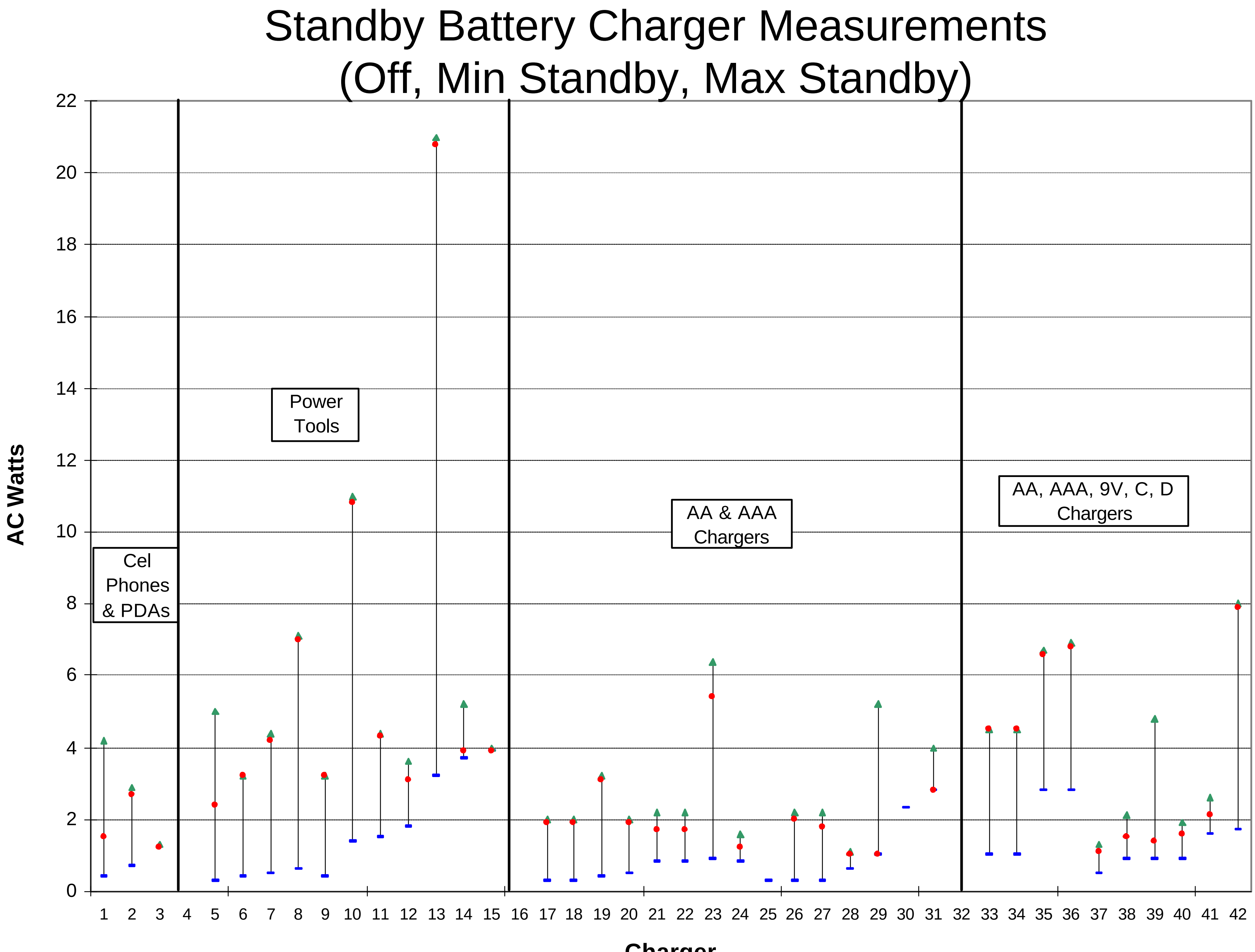
Money Isn't All You're Saving

No requirements for active power use

Results: Standby Energy Losses

	Maximum (W)	Average (W)	Minimum (W)	Sample Size
Cell Phone Charger	8.6	8.6	8.6	1
Cordless Phone	5.0	2.8	1.1	26
Rechargeable Personal Care Product	3.6	1.5	0.4	7
Cordless Power Tool	4.6	2.3	0.63	8
Rechargeable Lawn Care	4.3	3.6	2.8	2
Handheld Vacuum Cleaner	2.6	2.1	1.7	4
Multi-Purpose Battery Charger	1.5	1.0	0.2	5
Rechargeable Toy	2.2	2.2	2.2	1
Total Battery Charger	8.6	2.5	0.2	54

From David Floyd, Florida Solar Energy Center, and Carrie Webber, LBNL, “Leaking Electricity: Individual Field Measurement of Consumer Electronics,” 1998.

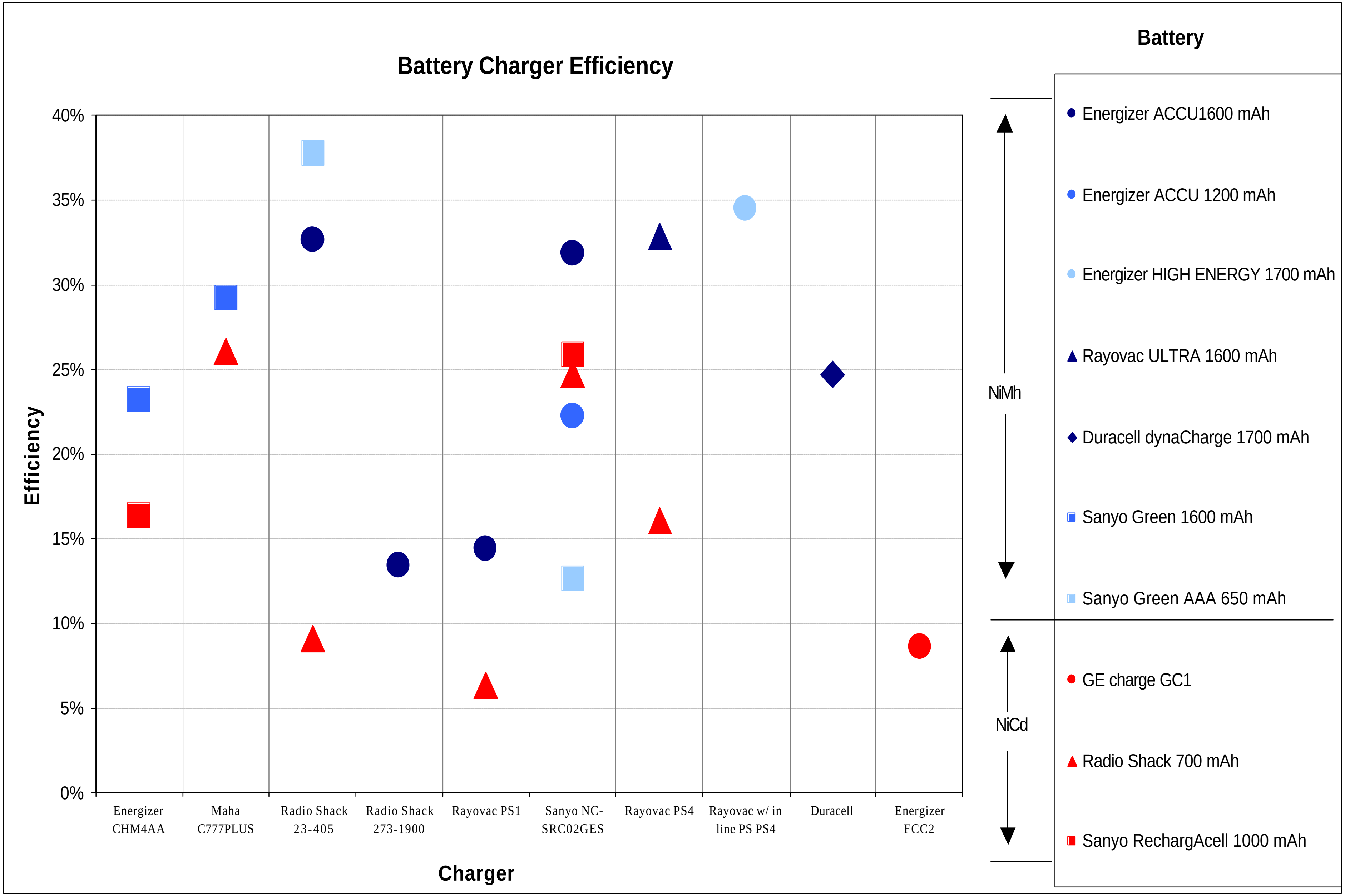

Standby Battery Charger Measurements
(Off, Min Standby, Max Standby)
AC Watts
Charger
0
2
4
6
8
10
12
14
16
18
20
22
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42
Cel Phones & PDAs
Power Tools
AA & AAA Chargers
AA, AAA, 9V, C, D Chargers

Estimate of Residential Battery Charging System Standby Losses

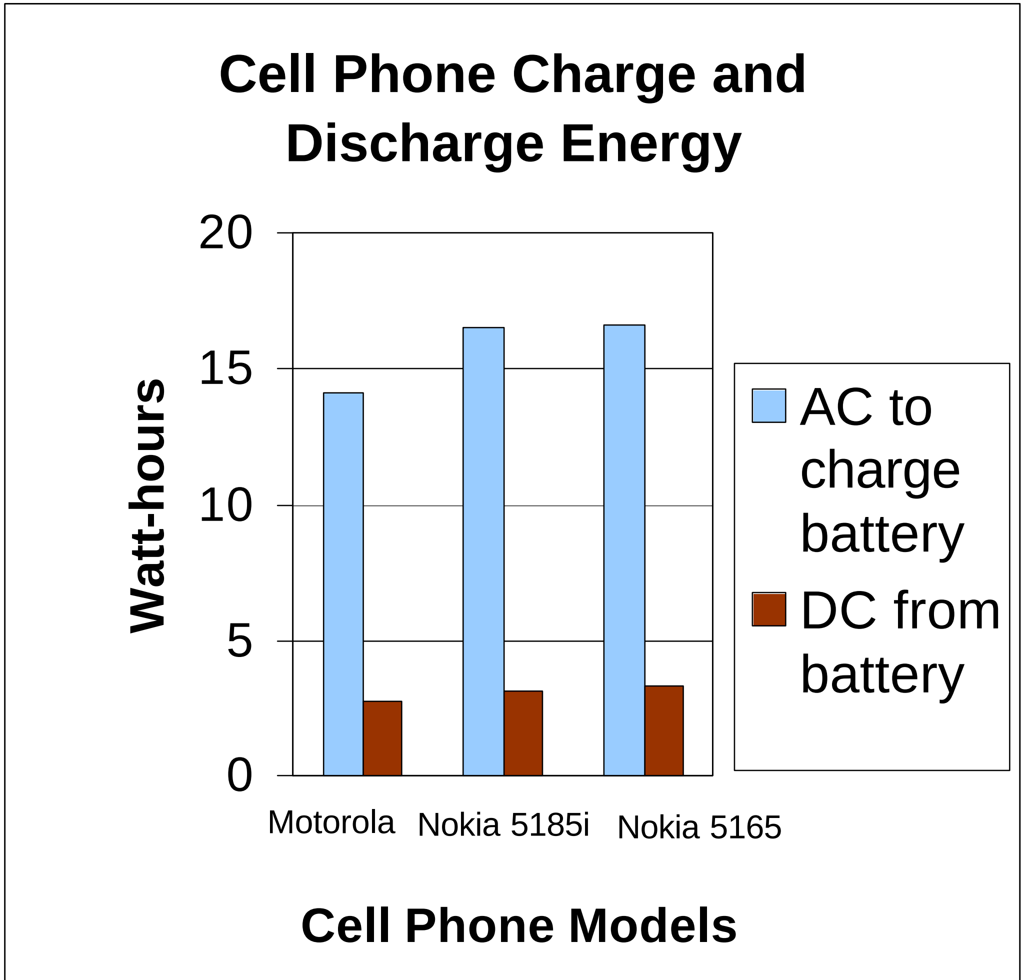
- Roughly 8 billion kwh lost per year nationally to battery charger standby mode
- < ½% of national residential electricity consumption
- Translates to 30 million dollars, 2 million tons of CO_2 emissions

Active Mode Results: AA Battery Systems

- Active Efficiencies from 6% - 40%
- Eff= $DC_{\textbf{batt energy}}/AC_{\textbf{charge energy}}$
- Discharge rate 300mA (regardless of capacity)
- Utilized different battery and charger combinations

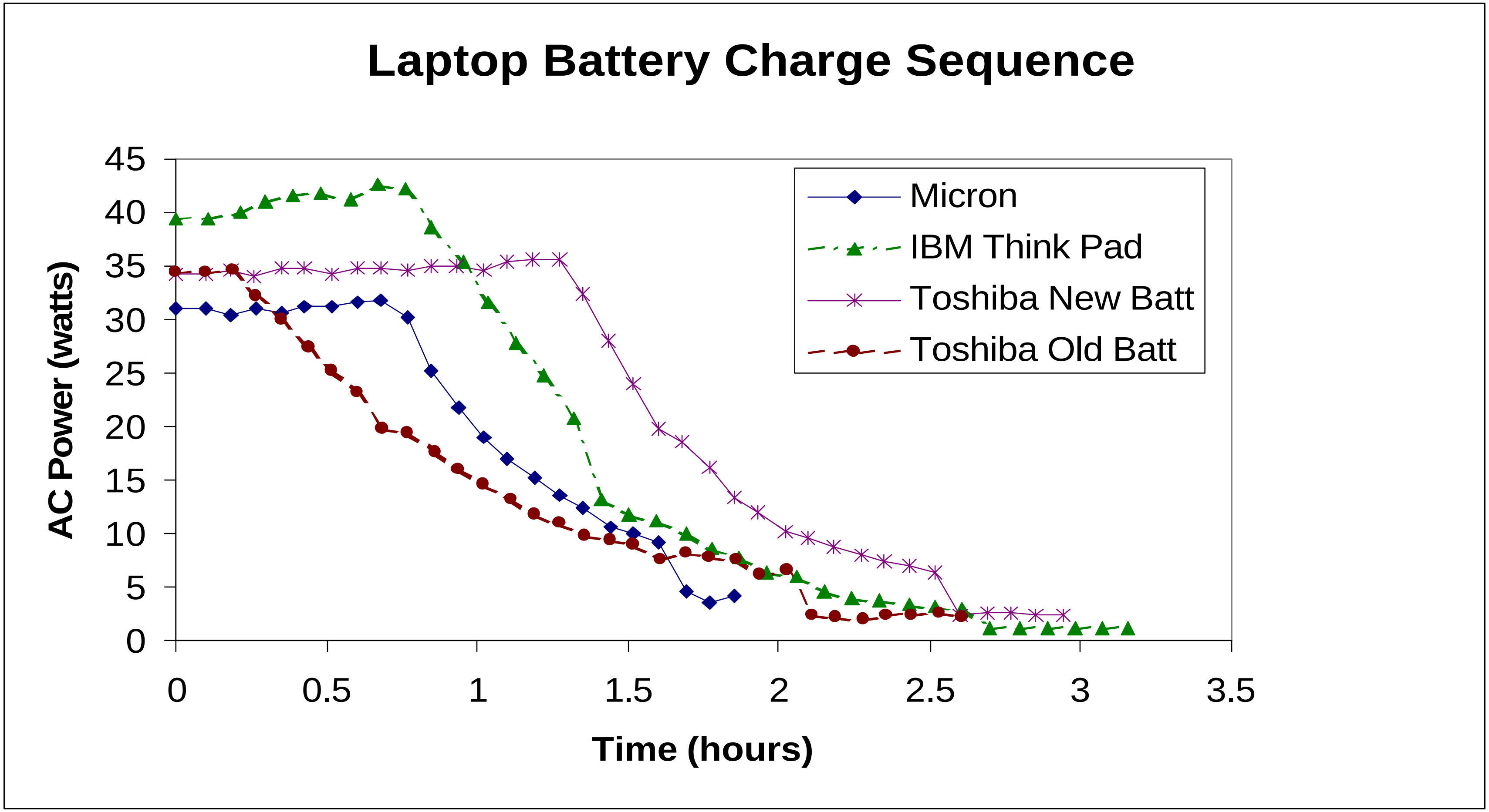

Battery Charger Efficiency
Efficiency
40%
35%
30%
25%
20%
15%
10%
5%
0%
Energizer CHM4AA
Maha C777PLUS
Radio Shack 23-405
Radio Shack 273-1900
Rayovac PS1
Sanyo NC-SRC02GES
Rayovac PS4
Rayovac w/ in line PS PS4
Duracell
Energizer FCC2
Charger
Battery
NiMh
NiCd
Energizer ACCU1600 mAh
Energizer ACCU 1200 mAh
Energizer HIGH ENERGY 1700 mAh
Rayovac ULTRA 1600 mAh
Duracell dynaCharge 1700 mAh
Sanyo Green 1600 mAh
Sanyo Green AAA 650 mAh
GE charge GC1
Radio Shack 700 mAh
Sanyo RechargAcell 1000 mAh

Results: Cell Phone Battery Systems



- EFF= DC_{batt}/AC_{charge}
- Efficiency = 20%
- Discharge Rate = 1C
- Charge while cell phone is off
- Little variation

Results: Laptop Battery Systems



Efficiencies from 59% - 68%

Active Mode Energy Consumption

- EPA and other regulatory bodies are moving toward active power in a number of products
- Active mode energy consumption often larger than standby mode energy consumption, particularly for frequently used products like laptops

Annual Active and Standby Energy of a Commercial Power Tool

	Hours	Watts	# of charges	Watt-hours	Stock	Kwh/ Year
Base Case						
Active			208	50		11
Standby	520	3				2
Efficiency Improvement Case						
Active			208	40		8
Standby	520	2				1
Potential Energy Savings						
				Active		**3**
				Standby		**1**

Where is the Energy Going?

- **Power Supply Losses**
  - Energy lost converting AC 120 V to lower DC voltages
- **Electrical Losses**
  - Continuous low power charging (NiCd)
- **Chemistry-Dependent Losses**
  - Interaction between battery chemistry and charging function
  - Inherent electrochemical losses

Typical Low vs. High Efficiency

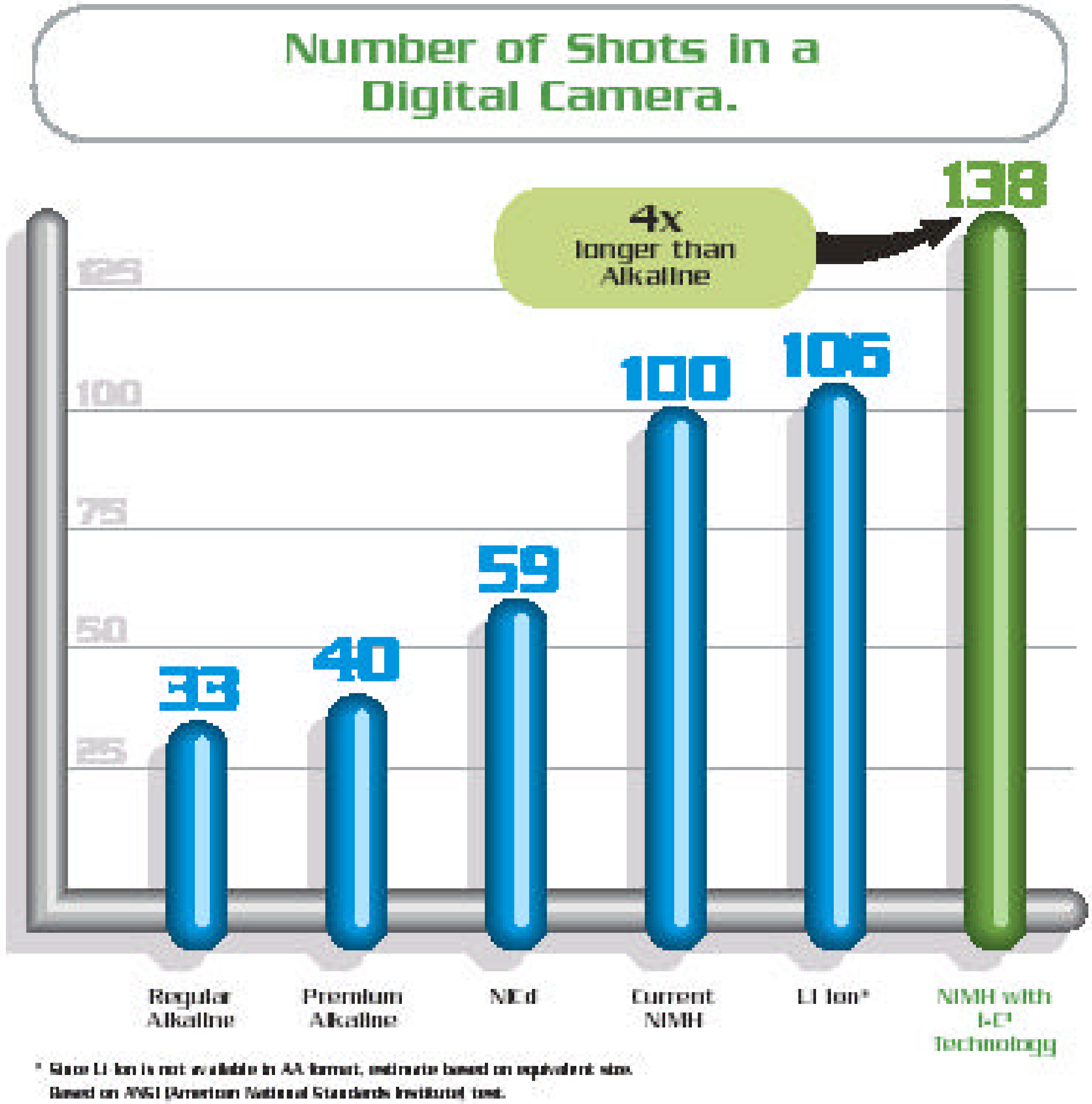
Low Efficiency (6-40%)	**High Efficiency (60-70%)**
Includes most residential battery systems: NiCd, NiMH	Includes premium chemistries: Li-Ion & Li-Polymer
No thermal regulation	Smart Battery
Inefficient power supply (20%-50%)	Highly efficient power supply (85%-90%)

Possible Technical Solutions

- **Efficient Power Supplies**
  - External to battery charging technology
  - Potentially inexpensive
- **Smart Battery Technology**
  - Internal to battery charging technology
  - More expensive initially; cost likely to fall over time

Smart Battery Technology

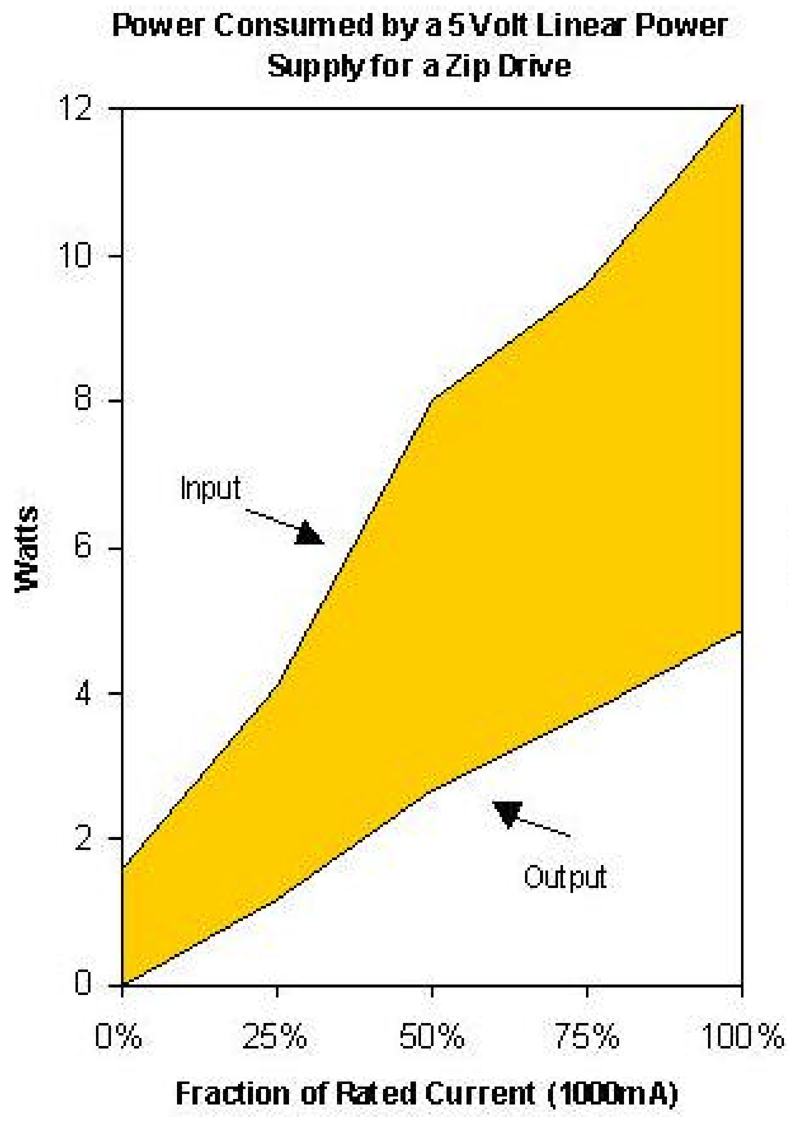
- More efficient
- Improved performance
  - Longer life
  - Increased capacity

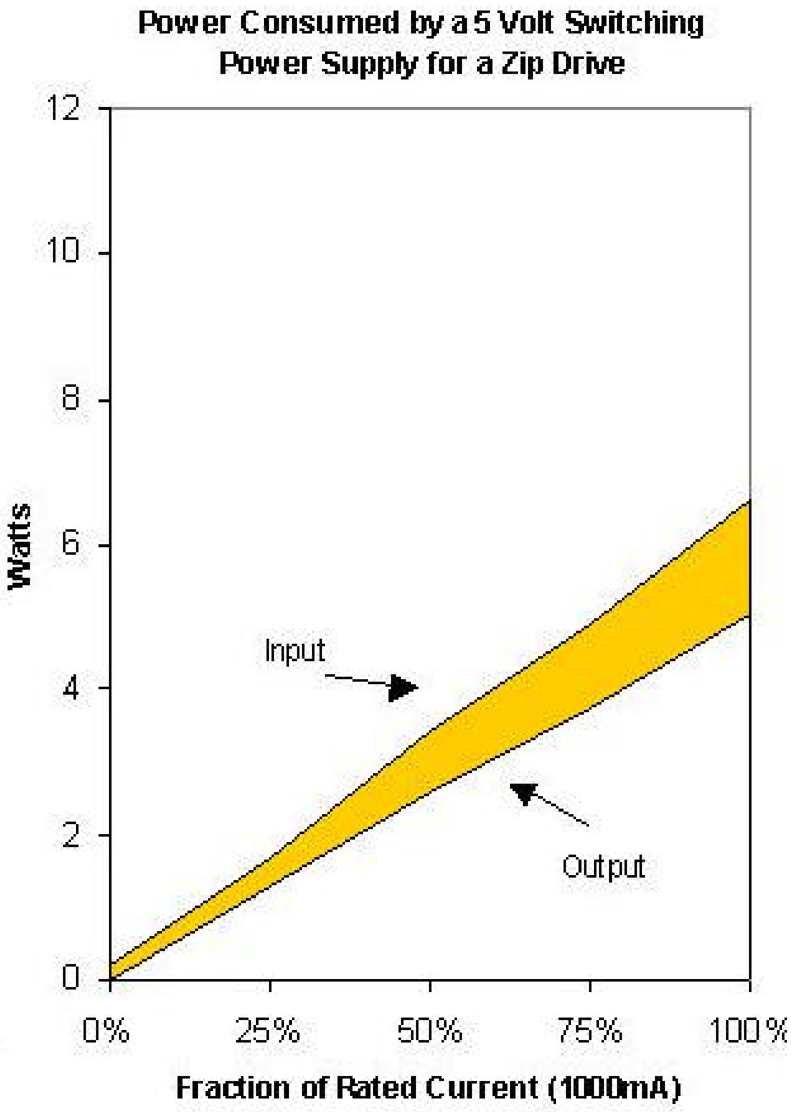


Power Supply Efficiency

Device	Overall Efficiency	Power Supply Efficiency	Charge Efficiency	Discharge Efficiency
Best Case				
Laptop	60%-70%	80+ %	90%	90%
AA Charger	6%	40%-50%	< 50%	< 50%
Worst Case				

Efficiencies of Two Power Supplies

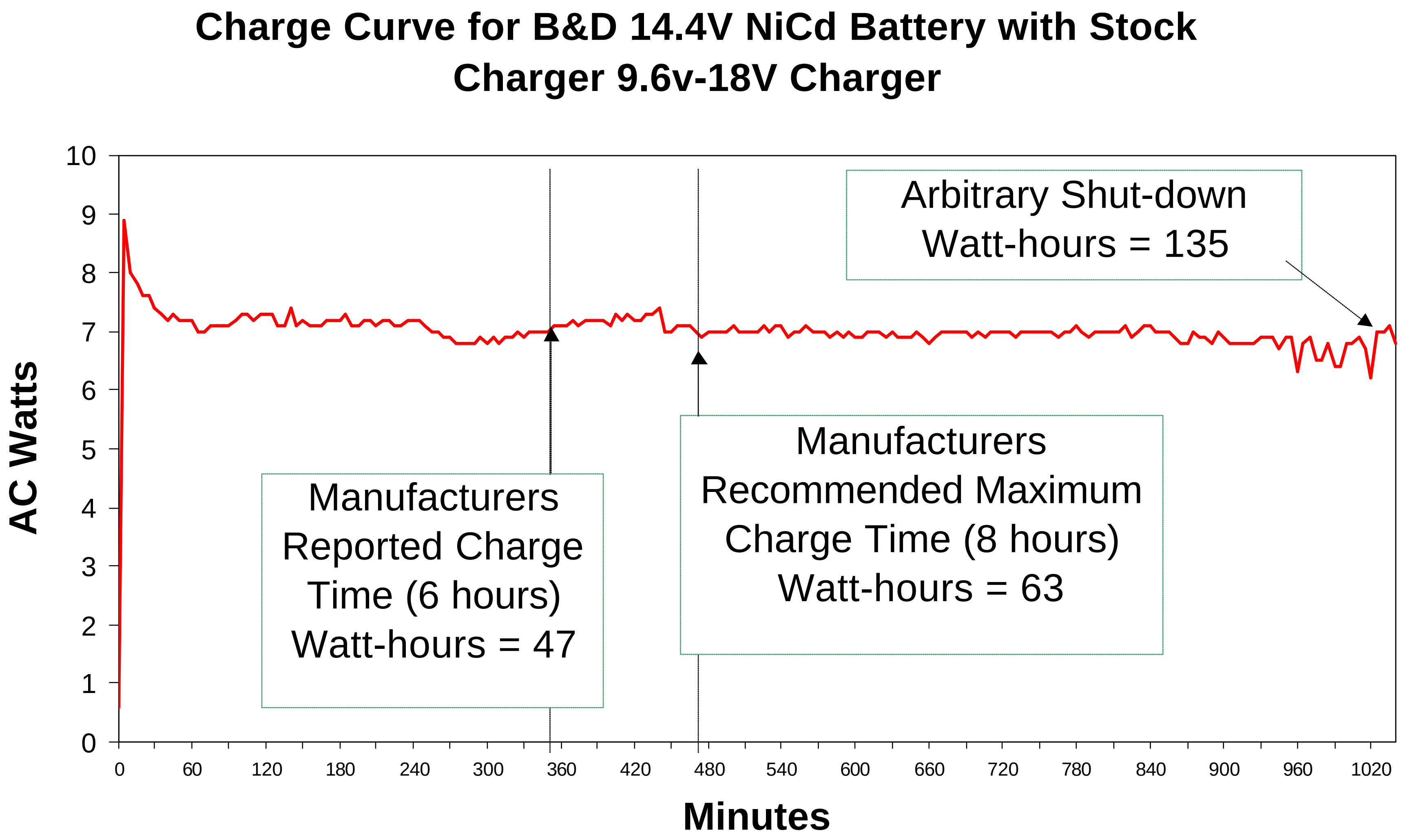




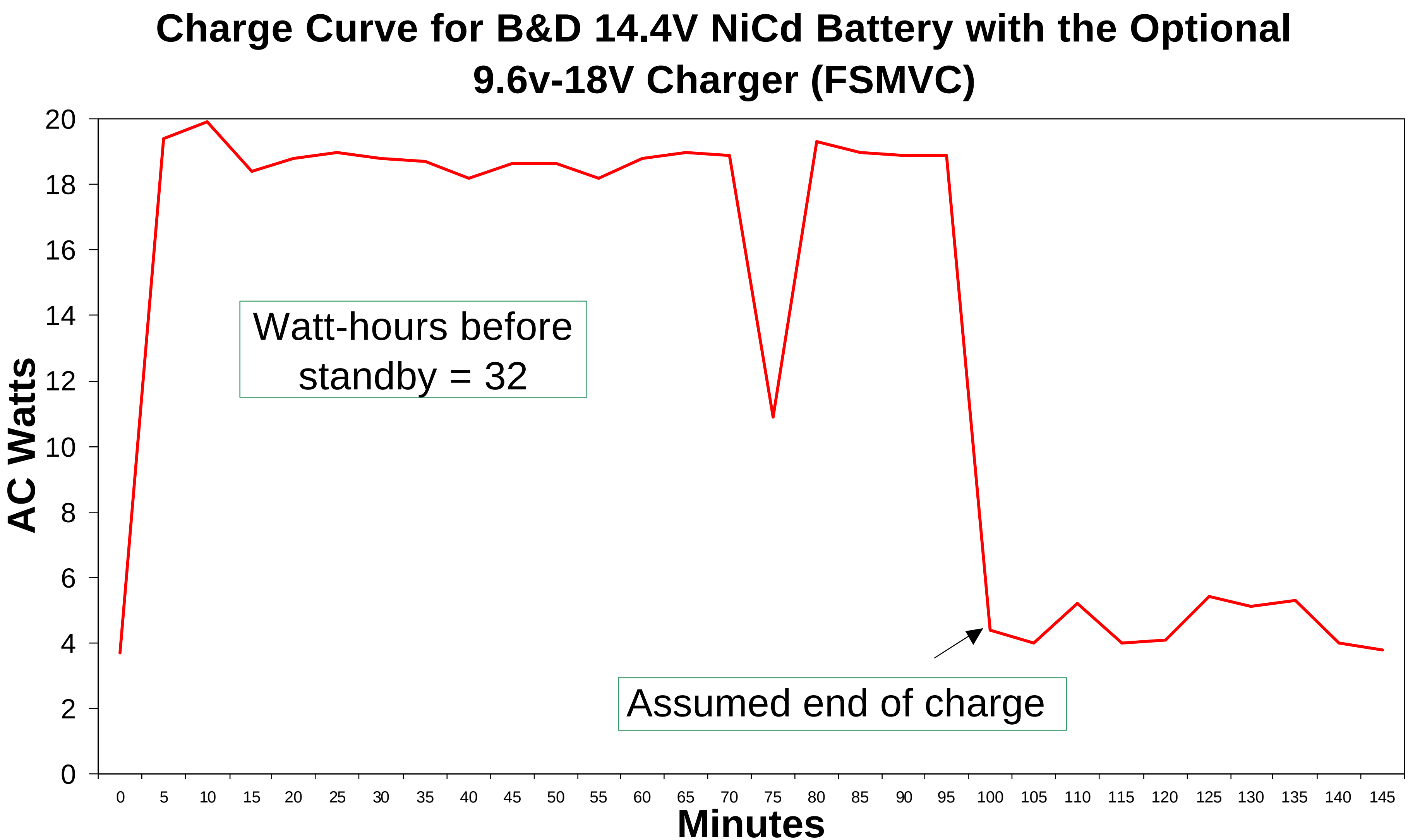
Other Advantages of Better Power Supplies

Reduced shipping and packaging cost; Small form factor

Budget Charger Design



Smart Charger Design



Possible Market Solutions

- What is needed?
  - Test methodology for energy efficiency metric
  - Standardized labeling ie: battery capacity
- Possible role for ENERGY STAR
- Procurement Policies (State, Federal, Local governments, private?)
- Utility incentives?

Environmentally Preferable Procurement

- Must first be able to distinguish between products (ENERGY STAR and Exec Order)
- Institutions required to purchase products that are environmentally ‘friendly’
- Examples: King County - WA, State of North Carolina
- Large procurement allows environmental products to penetrate the market; Can be an incentive to manufacturers

Possible Industry Solutions

- Participate in process to develop a consensus test method for battery charging systems
- Improve the design of your systems: work to improve both active and standby performance
- Purchase more efficient power supplies
- Encourage EPA to set an ENERGY STAR spec for battery chargers and/or power supplies

Summary

- Standby mode national standards exist now and active mode measures are coming
- Energy Efficiency
  - Better thermal control
  - Minimize product size, packaging & shipping costs
  - Market as an eco product as chemistries transition from nicad to nimh and li-ion
- Reduce air pollution and slow global warming

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