POWER SUPPLIES:

A Hidden Opportunity for Energy Savings

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Executive Summary

Introduction

Although nearly all home electronic products and office equipment plug directly into wall outlets and draw 120 volts of alternating current (AC), most of their circuitry is designed to operate at a much lower voltage of direct current (DC). The devices that perform that conversion are called power supplies. Power supplies are located inside of the product (internal) or outside of the product (external). Most external models, often referred to as “wall-packs” or “bricks,” use a very energy inefficient design called the linear power supply. Our measurements of linear power supplies confirmed energy efficiencies of 20 to 75%. Most homes have 5 to 10 devices that use external power supplies, such as cordless phones and answering machines.

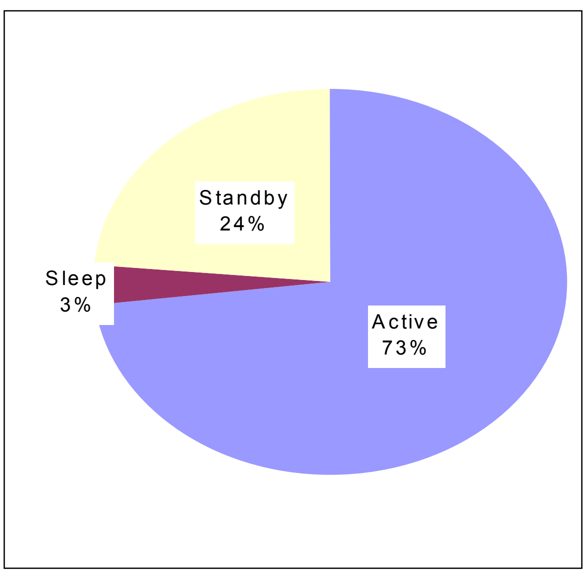
Internal power supplies are more prevalent in devices that have greater power requirements, typically more than 15 watts. Such devices include computers, televisions, office copiers, and stereo components. Most internal power supply models use somewhat more efficient designs called switching or switch-mode power supplies. Our measurements of internal power supplies confirmed energy efficiencies of 50 to 90%, yielding wide variations in power use among similar products. Power supply efficiency levels of 80 to 90% are readily achievable in most internal and external power supplies at modest incremental cost through improved integrated circuits and better designs.

Energy Saving Potential and Environmental Impacts of Improved Power Supplies

Nearly 2.5 billion electrical products containing power supplies are currently in use in the United States, and about 400 to 500 million new power supplies (linear and switching) are sold in the U.S. each year. The total amount of electricity that flows through these power supplies is more than 207 billion kwh/year, or about 6% of the national electric bill. More efficient designs could save an expected 15 to 20% of that energy. Savings of 32 billion kwh/year would cut the annual national energy bill by $2.5 billion, displace the power output of seven large nuclear or coal-fired power plants, and reduce carbon dioxide emissions by more than 24 million tons per year.

The Significance of Active Mode Energy Consumption

Figure 1 – Percentage of Total Energy Consumed in Each Operating Mode



Our research suggests that, on average, about 73% of the total energy passing through power supplies occurs when the products are in active use (Figure 1). Sleep and standby modes, though they account for most of the hours of operation in the majority of products, represent much smaller overall energy use.

Many products like televisions and computers only spend a few hours per day in active mode but consume far more energy during that time than they do in the longer periods spent in sleep and standby modes. This is easy to see in the following table, which summarizes typical energy use in each operating mode for televisions, computers, and monitors.

Product	Active kwh/year	Sleep kwh/year	Standby kwh/year	Total kwh/year
Analog Television	105.1	0.0	33.8	138.9
Office Computer	296.1	18.0	6.6	321.0
Office Monitor (CRT)	291.5	19.4	7.5	318.4

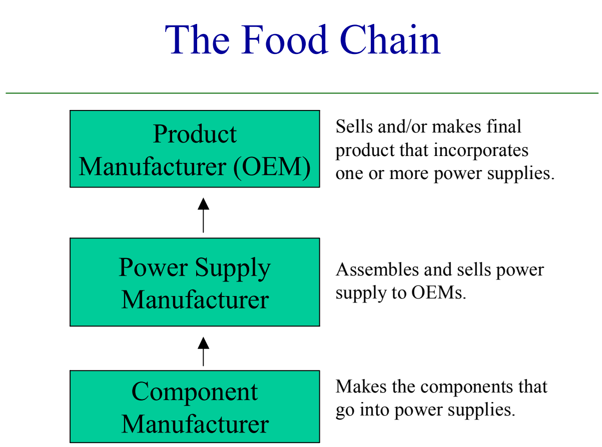
A number of efforts are already underway to reduce standby consumption in power supplies – the power used when the product is turned off or not performing its intended service. NRDC supports these efforts, since standby power use per home is roughly 70 to 125 W and could be greatly reduced through simple design changes. However, many of the technological approaches used to reduce standby power do not automatically improve active mode efficiency – the power used when the product *is* performing its intended service. The most advanced power supply technologies can reduce standby energy consumption, and improve full and partial load efficiency. Given the much larger potential energy savings that can be obtained from the active mode, policy makers and efficiency program designers should move beyond their current focus on sleep and/or standby power usage and add consideration of active mode energy usage as well.

<u>The Power Supply Market – Why Aren't Better Power Supplies Included in Today's Electronics Products?</u>

Our research indicates that the efficiency of most linear power supplies could be improved from the 50 to 60% range to 80% or more. Switching power supply efficiencies could be increased from the 70 to 80% range to roughly 90%. In most cases, the incremental cost for the improved power supply is less than $1. The resulting electricity savings for these products pay for their incremental cost very quickly – typically in 6 months to a year.

Unlike many other energy efficiency technology challenges, the efficient power supplies and the components that go into them are widely available. The need is not to invent a better components or finished power supplies, but simply to encourage the market to utilize the better designs that already exist. This primarily means convincing assemblers of electronic products to specify more efficient power supplies in their product design process, as evident in Figure 2.

Figure 2 – The Power Supply "Food Chain"



The principal challenge is that the purchaser of the power supply is not the one that pays the electric bill. While the consumer pays the electric bill, it is the large companies such as Sony, Hewlett Packard, and Black and Decker that buy the power supplies for use in their TVs, computers, cordless telephones, and portable vacuums and power tools. This is a classic split incentive case where the purchaser, of the power supplies, is not the one that benefits directly from the reduced electricity bills.

To compound the situation, most consumers do not consider the annual energy consumption of a product when they go to purchase one of these products and even if they were so motivated, little to no information is available for them. (Unlike household appliances, there is no Energy Guide label or equivalent for purchasers to use to compare the performance and operating costs of similar products).

Though the energy efficiency benefits of better power supplies are compelling, the non-energy benefits may be even more important to the companies that purchase power supplies for their finished products, the retailers that sell them, and the consumers that buy them. Highly efficient power supplies tend to be smaller, lighter in weight, and more convenient. They operate at cooler temperatures, contain fewer parts, and are likely to result in greater product reliability.

Other product design changes can yield substantial energy savings as well, reducing the need for active ventilation within the product and causing far lower draw on the power supply itself. In fact, efficiency savings on the DC side of a circuit offer an automatic bonus, since each watt saved can yield as much as four watts of savings at the 120 volt AC side of the utility meter when power supplies are only 25% efficient.

The market for power supplies fails to capture these energy savings at present because the products are obscure and their energy efficiency is generally unknown. No clear labeling of efficiency is currently done, and power supplies are often oversized to minimize liability, wasting additional energy when the products operate at part load. The highly competitive electronics industry places a premium on very low manufacturing cost, so even technologies that increase cost by pennies can be rejected as too expensive.

Regulatory Status of Power Supplies

Power supplies themselves are virtually unregulated worldwide from an energy efficiency standpoint. A European "Code of Conduct" addresses only standby power consumption for external power supplies drawing 75 watts or less. In the U.S., there are no utility programs promoting more efficient power supplies. Likewise, voluntary labeling programs like ENERGY STAR for consumer electronics and office equipment currently only address standby and/or sleep mode power consumption. They do not focus specifically on power supply efficiency, and miss the big percentage savings opportunity from active mode in a wide variety of electronic products.

There is considerable activity in the US that is directed at improving the efficiency of products containing power supplies. The EPA has demonstrated a willingness, where appropriate, to address all three operating modes – active, sleep, and off (standby) – in its upcoming ENERGY STAR® product specifications. Through the President's Executive Order on Standby Power Use, most federal government agencies are required to buy products that consume little power in standby mode (1 watt in many products; more in others). Again, this is a great first step, but may not result in any reductions in active mode energy consumption.

Mandatory standards for power supply efficiency are currently under consideration in various proposed Congressional energy bills, though the focus is primarily on standby power use. Likewise, the California Energy Commission is evaluating proposed standards that would improve standby and active mode efficiency for power supplies, though the process is in its early stages and the effective date for such a standard would be many years in the future.

Recommendations

More coordination is warranted between international, federal, and state standards organizations, as well as voluntary industry groups and efficiency program implementers. A wide range of approaches could turn out to be helpful, including utility incentives to overcome higher purchase prices, voluntary or mandatory labeling programs, procurement specifications, and state or federal efficiency standards. It is difficult to pick the most promising approaches this early in the research process, but we offer the following initial recommendations:

- Manufacturers and consumers will benefit greatly from an effort to label power supply efficiency in a clear, standardized way. The current distinction between standby power consumption and active mode efficiency tells only part of the story. Standardized efficiency "curves" that state efficiency across the full range of operating conditions would allow specifiers and procurement officers to readily identify and purchase products that are more efficient overall.

- Voluntary efficiency labeling programs such as ENERGY STAR should account for all energy-consuming modes – active, sleep, and standby – when new specifications are created or older ones are updated for consumer electronics, office equipment, telecommunications products, and appliances. Doing so will increase overall energy savings significantly, since many products consume more energy in active mode than during the longer periods of time when they are not in use. It may make sense to label or regulate power supplies themselves, given their pervasive use in such a diverse array of products.

- Promising end-uses for an early focus on improved power supply efficiency include television sets, computers, and monitors. In most cases, these products have high active power consumption, long hours of operation, or a large percentage opportunity to improve efficiency, with savings accruing across millions of units of annual U.S. sales. We also see compelling opportunities with battery chargers – both the standalone type used for typical consumer battery sizes and the external AC adapters/battery chargers employed by cellular phones and laptop computers. A product-by-product approach is recommended as each one has its own unique supply chains, product requirements, non-energy benefits, and potential solutions.

- Additional research is needed to learn more about the costs and benefits of better power supplies, particularly in high wattage products. In addition, more measurements are needed of when power supplies are operating and how much power they use, particularly in active mode, to better target efficiency programs. A good deal of market research has already been done about current power supply sales and product characteristics, but the reports are proprietary and expensive so should be purchased on a targeted basis.

This research was funded by a grant from the U.S. Environmental Protection Agency to NRDC. The findings and conclusions are strictly those of the authors, and do not necessarily represent the views of the EPA.

Power Supplies: A Hidden Opportunity for Energy Savings

Introduction

While all electrical products require a power source, surprisingly few are designed to operate directly on 120 volts of alternating current (AC) from a wall outlet. In some cases, the reason is obvious – many portable electronic products like remote controls and music players operate directly from the low voltage direct current (DC) produced by batteries.

But the more important reason is the continuing growth in popularity of consumer electronics, whose integrated circuit chips, displays, and controls are designed to work directly from low voltage DC. While these products could operate from batteries, that is a costly way to provide power, especially for products that do not need to be portable. Instead, these products employ *power supplies* – special circuits designed to reduce wall voltage from 120 volts to something in the range of 3 to 15 volts, then convert it to DC, and then smooth and regulate the final output to a specific level.[1]

Sometimes, this conversion is performed in a separate box outside of the main product. These rectangular plastic enclosures are substantially larger and heavier than a standard wall plug. They accomplish their power conversion right at the wall outlet, and then send the resulting DC power over a thin pair of wires to a jack on the final load. They allow manufacturers to save money on UL listings, since listing is only needed for the power supply and not for the low voltage DC device that connects to it. These *external power supplies* are also known by a wide range of colorful names, such as "AC adapter," "brick," "wall wart," "wall pack," "transformer," "fat snake," and "vampire."

The conversion can also be performed within the final product, especially for products that are not intended to be portable or that consume fairly high amounts of power. These *internal power supplies* are less likely to be noticed by the consumer, but still perform the functions of reducing voltage, rectifying it, and sending the resulting power to IC chips and other electronic circuits.

The reason power supplies have become so important to the energy efficiency community is that most home electrical products (including major appliances) now require power supplies to operate. Between those products and a wide array of office equipment, consumer electronics, and telecommunications equipment, there are now roughly two billion power supplies sold globally each year. And the vast majority of them use far more energy than necessary, relying on bulky, inefficient transformer designs that are nearly a century old.

The technology exists to increase the energy efficiency of these power supplies significantly, both when they are operating at full load and when they are in "standby" mode. Such technologies have very minor incremental costs in the near term and provide a host of non-energy benefits. The resulting energy savings and environmental benefits would be enormous, yet virtually invisible to the end user.

Given the lack of analysis performed to date on the power supply market from an energy savings perspective, NRDC retained Ecos Consulting to measure the energy efficiency of existing power

[1] The term "power supply" is often applied more broadly to also include DC/DC converters (products that change one DC voltage to another). While these products also represent an energy savings opportunity, we focus here on AC/DC power supplies only.

supplies, gather relevant market research, assess energy savings opportunities, and make policy recommendations.[2] This paper provides a summary of the work completed to date and includes:

- An assessment of the power supply market
- A description of the various types of power supplies that are available and their efficiency
- The results of energy consumption measurements taken of selected devices in their active, standby and sleep modes.
- Policy recommendation on how to accelerate the use of energy efficient power supplies in home and office electronics products

Current Technologies

Most external power supplies contain a transformer, which employs two different coils of wire and the magnetic field between them to lower the output voltage to the desired level. These low frequency, "linear" power supplies are somewhat akin to magnetic ballasts in the lighting world – they are bulky, cheap and energy inefficient, because they convert electricity into heat, not unlike an electric resistance heater.

The linear power supply is the most widely used, especially for products that consume less than 15 watts of power. As a result, they are more commonly found in external power supplies than internal ones. More than a billion external power supplies are sold globally each year, and the average U.S. home contains perhaps 5 to 10 of them.[3] Typical applications that have an external power supply include: cordless phones and answering machines, video games, computer speakers, cordless tools, etc. Including commercial uses, there may well be more than a billion of these products in operation in the U.S. alone.

Other types of power supplies work at much higher frequencies than 60 hertz, and utilize predominantly solid-state components. These "switch-mode" or "switching" power supplies are analogous to electronic ballasts in the lighting world. They tend to be more compact, slightly more expensive, and substantially more energy efficient. They are more commonly found in higher wattage products like desktop computers, televisions, and microwaves. Because switching power supplies produce less heat than standard models, they are often placed inside the product, rather than used externally.

Linear power supplies for cellular phones and portable disk drives can often exceed the size and weight of the device they are intended to power. For example, Iomega Corporation made the decision to upgrade its Zip drive power supplies (Figure 1) from the unit on the right to the unit on the left. The difference in weight was the primary reason for upgrading the Zip power supply. The old unit weighs more than a pound and the new one is a mere three ounces. In addition, of course, the smaller power supply cuts power consumption by roughly 50%.

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[2] This research was funded by a grant from the U.S. Environmental Protection Agency to NRDC. The findings and conclusions are strictly those of the authors, and do not necessarily represent the views of the EPA. Comments and questions should be directed to Noah Horowitz (nhorowitz@nrdc.org) or Chris Calwell (calwell@ecosconsulting.com).
[3] Personal Communication, Balu Balakrishnan, VP of Engineering and Strategic Marketing, Power Integrations, May 2001. See also Alan Meier, *Standby Energy Use and Energy Savings Opportunities*, presented at Power Supplies Workshop, San Francisco, January 14, 2002.

Likewise, we have recently purchased samples of consumer battery chargers and USB hubs in which the power supply is substantially heavier than the product to which it is connected. Not surprisingly, highly efficient switching power supplies (internal or external) often first become popular with portable products, where business travelers are willing to pay a small premium for compact, lightweight designs.

Figure 1 – Switch Mode and Linear External Power Supplies

Market Assessment

Current U.S. demand for internal power supplies is about $4 billion/year, and it is growing by nearly 10% annually.[4] North American sales of external power supplies are roughly $1 billion per year, with approximately 80% of that representing switching models and 20% representing linear models.[5] On a units basis, the total is about 200 million units per year, split between 54% switching and 46% linear models, according to Ecos estimates.[6]

The global wholesale market for internal switching power supplies (including related products known as "DC/DC converters") was over $11.3 billion in 2001 according to one source.[7] Another source estimated that the worldwide market in 2000 for internal switching power supplies alone was $13.6 billion, and growing by about 9% per year.[8] Yet another source estimated that AC/DC switching power supply sales alone were more than $12.5 billion and nearly 132 million units globally in 2000.[9] (Numerous sources noted that 2001 saw a decline in global power supply sales, however, because of a weakening economy). Given that power supplies used in computers have an average wholesale cost of about $15 to $20, it is conceivable that these global sales represent perhaps 500 million to 1.5 billion units per year. Taking all the published estimates together and scaling them geographically, gives the following very approximate overall picture for power supply sales and use:

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[4] Arthur Zaczkiewicz, "Power-supply market fired up," *EBNews.Com*, January 12, 2000.
[5] Darnell Group, *AC/DC External Power Supplies: Global Market Forecasts and Competitive Environment*, July 2000, p.67.
[6] Ecos Consulting, *Analysis of Energy Efficiency Standards Options for External Power Supplies*, for Davis Energy Group, draft, publication pending.
[7] Venture Development Corporation, Merchant Markets and Applications for AC/DC Switching Power Supplies, DC/DC Converters, and Telecom Rectifiers: North America and Europe, November 2001, online summary found at www.vdc-corp.com/products/br01-11a.html.
[8] See www.darnell.com, *AC/DC Power Supplies: Worldwide Market Forecasts, Competitive Environment and Industry* Trends; and Power Sources Manufacturers Association, *Market Update*, July 1, 2001, www.psma.com/HTML/FILES/PSMA_MktUpdate_2001_07.pdf, citing research by Mohan Mankikar, Micro-Tech Consultants, www.micro-techco.com.
[9] Frost and Sullivan, *World AC/DC SPS Market*, report # 7287-27, 2001, p. 1-4.

Table 1 – Estimated Power Supply Sales and Number in Use

	North America		Global	
Power Supply Type	Unit Sales/Year	Total Units in Use	Unit Sales/Year	Total Units in Use
External	>200 million	>1.0 billion	>1 billion	>3 billion
Internal	>250 million	>1.5 billion	0.5 to 1.5 billion	>3 billion
TOTAL	>450 million	>2.5 billion	>1.5 to 2.5 billion	>6 billion

The switching power supply market is somewhat heavily concentrated in the hands of a few large manufacturers. Emerson, Tyco Electronics, and Delta Products collectively represented global sales of about $4.5 billion (33% of the total) and North American sales of about $2.9 billion (about 40% of the total).[10] There are likewise a handful of current suppliers of the integrated circuits that greatly improve power supply efficiency. These companies include Power Integrations, OnSemi, International Rectifier, Motorola, and Philips Semiconductors, among others. Companies that specialize in the manufacturing of complete highly efficient power supplies include Bias Power Technology, Celetron, N2 Power, Power Density, and others. The term "manufacturer" can be somewhat confusing in the power supply business. The integrated circuit manufacturers supply parts to the power supply manufacturers, who in turn sell those complete circuits to the product assemblers that build VCRs, televisions, cordless phones, etc. from various component parts. See Figure 9, below, for a more complete discussion of the key market actors and leverage points.

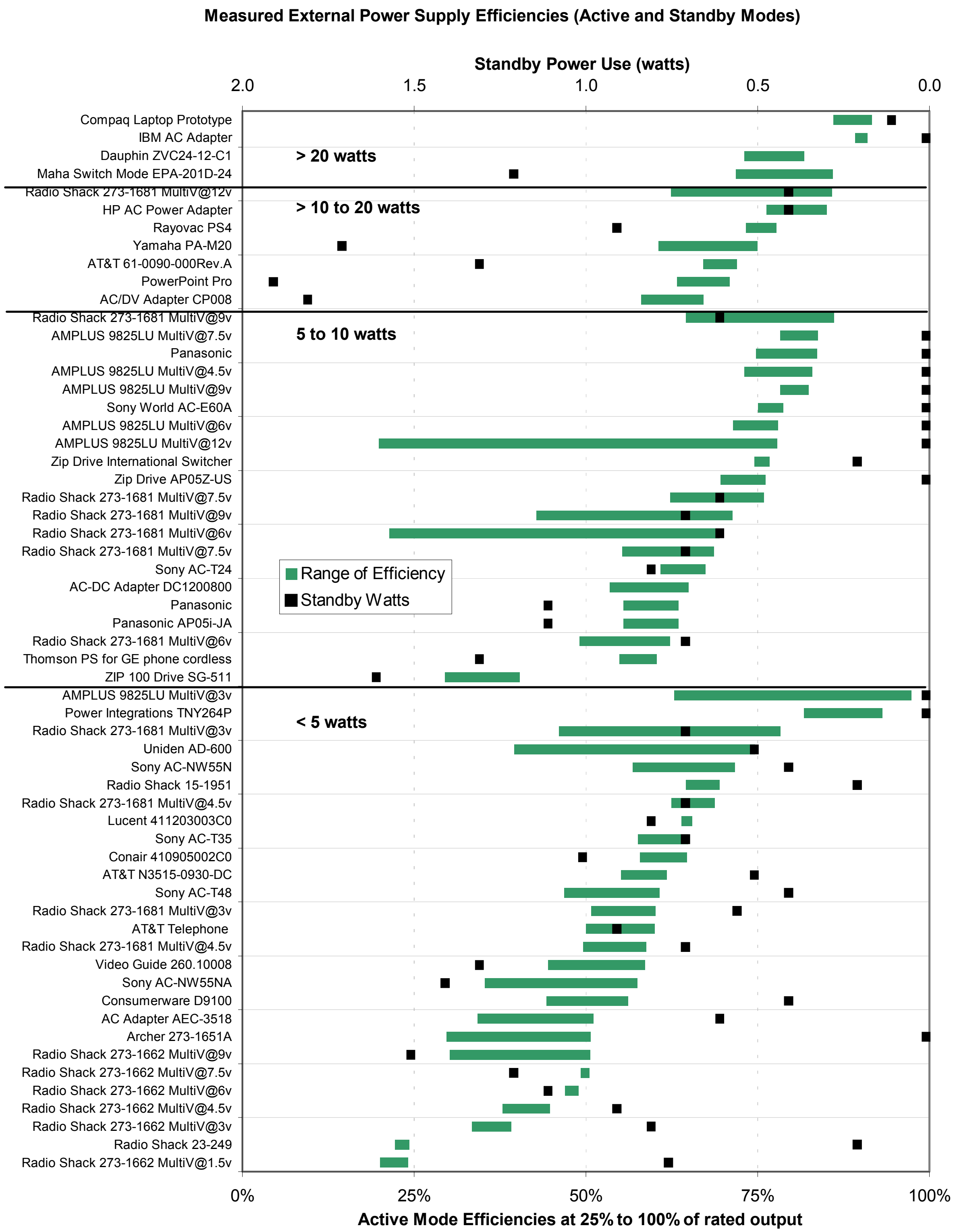
How Much Energy is Wasted by Power Supplies?

Power supplies not only convert energy – they consume it. For every kwh that goes into a power supply, a smaller amount of energy comes out. The efficiency of a power supply is determined by dividing output power by input power.[11] Typical efficiencies when a product is operating are about 25 to 60% for linear power supplies and about 50 to 90% for switching power supplies. This means that a product that works entirely in DC, like an answering machine, could consume 50% less power when operating if its power supply were upgraded from 40% efficiency to 80% efficiency.[12] Savings can occur not only from using switching power supplies instead of linear, but also from specifying *highly efficient* switching power supplies.

Our measurements of a variety of electronic products yielded a wide range of efficiency levels for external power supplies (Figure 2). Efficiencies were usually higher with the original factory power supply provided with the unit than with after-market, "universal" adapters. It is simply easier to optimize a power supply for energy efficiency when it is intended to operate at a single voltage and relatively high load (see part load efficiency discussion below). Note that standby power consumption varied from a low of <0.01 watts to a high of nearly 2 watts, while active mode efficiencies ranged from as low as 20% to more than 90%.

[10] Micro-Tech Consultants, *Global Switching Power Supply Industry Report 2001*, www.micro-techco.com.
[11] Input power is normally given in watts AC. Output power is frequently specified in DC volts and amps, which can be multiplied to determine wattage. If, for example, a power supply has a maximum input power of 100 watts, a DC output voltage of 5 volts, and a maximum output current of 6 amps, its peak load efficiency would be 30% (30 watts / 100 watts). This example ignores possible impacts of power factor.
[12] Some products, like television sets or refrigerators, contain both AC loads and DC loads. Improving power supply efficiency in those products would only affect a portion of total power load, so the percentage savings from doubling power supply efficiency would not be as great.

Figure 2



Measured External Power Supply Efficiencies (Active and Standby Modes)
Standby Power Use (watts)
2.0
1.5
1.0
0.5
0.0
Compaq Laptop Prototype
IBM AC Adapter
Dauphin ZVC24-12-C1
Maha Switch Mode EPA-201D-24
Radio Shack 273-1681 MultiV@12v
HP AC Power Adapter
Rayovac PS4
Yamaha PA-M20
AT&T 61-0090-000Rev.A
PowerPoint Pro
AC/DV Adapter CP008
Radio Shack 273-1681 MultiV@9v
AMPLUS 9825LU MultiV@7.5v
Panasonic
AMPLUS 9825LU MultiV@4.5v
AMPLUS 9825LU MultiV@9v
Sony World AC-E60A
AMPLUS 9825LU MultiV@6v
AMPLUS 9825LU MultiV@12v
Zip Drive International Switcher
Zip Drive AP05Z-US
Radio Shack 273-1681 MultiV@7.5v
Radio Shack 273-1681 MultiV@9v
Radio Shack 273-1681 MultiV@6v
Radio Shack 273-1681 MultiV@7.5v
Sony AC-T24
AC-DC Adapter DC1200800
Panasonic
Panasonic AP05i-JA
Radio Shack 273-1681 MultiV@6v
Thomson PS for GE phone cordless
ZIP 100 Drive SG-511
AMPLUS 9825LU MultiV@3v
Power Integrations TNY264P
Radio Shack 273-1681 MultiV@3v
Uniden AD-600
Sony AC-NW55N
Radio Shack 15-1951
Radio Shack 273-1681 MultiV@4.5v
Lucent 411203003C0
Sony AC-T35
Conair 410905002C0
AT&T N3515-0930-DC
Sony AC-T48
Radio Shack 273-1681 MultiV@3v
AT&T Telephone
Radio Shack 273-1681 MultiV@4.5v
Video Guide 260.10008
Sony AC-NW55NA
Consumerware D9100
AC Adapter AEC-3518
Archer 273-1651A
Radio Shack 273-1662 MultiV@9v
Radio Shack 273-1662 MultiV@7.5v
Radio Shack 273-1662 MultiV@6v
Radio Shack 273-1662 MultiV@4.5v
Radio Shack 273-1662 MultiV@3v
Radio Shack 23-249
Radio Shack 273-1662 MultiV@1.5v
> 20 watts
> 10 to 20 watts
5 to 10 watts
< 5 watts
Range of Efficiency
Standby Watts
0%
25%
50%
75%
100%
Active Mode Efficiencies at 25% to 100% of rated output

Our measurements for the efficiency of internal power supplies reveal higher efficiency numbers, consistent with the use of switching designs, but also still reveal room for improvement. Note in this case that power supply efficiency tends to rise with load (brighter picture on a video screen, louder sound on a stereo, etc.), but still varies widely across products.

Table 2 – Internal Power Supply Efficiency Measurements

					Settings			Total Input	Total Output	Power Supply
Product	Manufacturer	Model Code	Date Manufactured	Power	Brightness	Contrast	Volume	Watts	Watts	Efficiency
TV 50 Inch	Hitachi	50ES1k	Nov-93	OFF	NA	NA	NA	**3**	**0.0**	**0%**
TV 50 Inch	Hitachi	50ES1k	Nov-93	ON	50%	50%	0%	**187**	**146.3**	**78%**
TV 50 Inch	Hitachi	50ES1k	Nov-93	ON	50%	50%	100%	**206**	**169.7**	**82%**
TV 50 Inch	Hitachi	50ES1k	Nov-93	ON	0%	50%	0%	**172**	**138.7**	**81%**
TV 50 Inch	Hitachi	50ES1k	Nov-93	ON	100%	50%	0%	**204**	**160.6**	**79%**
TV 27 inch	RCA	F27351wn	Mar-94	OFF	NA	NA	NA	**7**	**0.0**	**0%**
TV 27 inch	RCA	F27351wn	Mar-94	ON	50%	50%	0%	**59**	**48.9**	**83%**
TV 27 inch	RCA	F27351wn	Mar-94	ON	50%	50%	100%	**64**	**51.3**	**80%**
TV 27 inch	RCA	F27351wn	Mar-94	ON	0%	50%	0%	**55**	**44.8**	**81%**
TV 27 inch	RCA	F27351wn	Mar-94	ON	100%	50%	0%	**74**	**67.1**	**91%**
TV 25 inch	Emerson	TC2556D	?	OFF	NA	NA	NA	**6**	**0.0**	**0%**
TV 25 inch	Emerson	TC2556D	?	ON	50%	50%	0%	**88**	**48.3**	**55%**
TV 25 inch	Emerson	TC2556D	?	ON	50%	50%	100%	**90**	**48.4**	**54%**
TV 25 inch	Emerson	TC2556D	?	ON	0%	50%	0%	**72**	**34.8**	**48%**
TV 25 inch	Emerson	TC2556D	?	ON	100%	50%	0%	**100**	**59.0**	**59%**
TV 13 inch	Sharp	13J-M100	Jul-97	OFF	NA	NA	NA	**4**	**0.0**	**0%**
TV 13 inch	Sharp	13J-M100	Jul-97	ON	50%	50%	0%	**50**	**32.6**	**65%**
TV 13 inch	Sharp	13J-M100	Jul-97	ON	50%	50%	100%	**51**	**33.4**	**65%**
TV 13 inch	Sharp	13J-M100	Jul-97	ON	0%	50%	0%	**43**	**28.6**	**66%**
TV 13 inch	Sharp	13J-M100	Jul-97	ON	100%	50%	0%	**55**	**35.8**	**65%**
Stereo	JVC	RX-515VTN	?	OFF	NA	NA	NA	**2**	**0.0**	**0%**
Stereo	JVC	RX-515VTN	?	ON	NA	NA	0%	**51**	**39.1**	**77%**
Stereo	JVC	RX-515VTN	?	ON	NA	NA	50%	**165**	**124.8**	**76%**
Stereo	JVC	RX-515VTN	?	ON	NA	NA	100%	**224**	**193.2**	**86%**
Stereo	Pioneer	SX-201	?	OFF	NA	NA	NA	**0**	**0.0**	**off**
Stereo	Pioneer	SX-201	?	ON	NA	NA	0%	**23**	**16.8**	**73%**
Stereo	Pioneer	SX-201	?	ON	NA	NA	50%	**118**	**107.1**	**91%**
Stereo	Pioneer	SX-201	?	ON	NA	NA	100%	**205**	**177.0**	**86%**
Monitor 21 inch	Philips	PA1209	?	OFF	NA	NA	NA	**18**	**0.0**	**0%**
Monitor 21 inch	Philips	PA1209	?	ON	0%	50%	NA	**103**	**73.4**	**71%**
Monitor 21 inch	Philips	PA1209	?	ON	50%	50%	NA	**114**	**77.3**	**68%**
Monitor 21 inch	Philips	PA1209	?	ON	100%	50%	NA	**121**	**80.6**	**67%**
Monitor 15 inch	AST	7L	Jun-96	OFF	NA	NA	NA	**0**	**0.0**	**off**
Monitor 15 inch	AST	7L	Jun-96	ON	0%	50%	NA	**58**	**36.4**	**63%**
Monitor 15 inch	AST	7L	Jun-96	ON	50%	50%	NA	**58**	**39.4**	**68%**
Monitor 15 inch	AST	7L	Jun-96	ON	100%	50%	NA	**63**	**43.4**	**69%**
Monitor 13 inch	Impression	cm1448mk	?	OFF	NA	NA	NA	**0**	**0.0**	**off**
Monitor 13 inch	Impression	cm1448mk	?	ON	0%	50%	NA	**53**	**38.4**	**72%**
Monitor 13 inch	Impression	cm1448mk	?	ON	50%	50%	NA	**56**	**42.0**	**75%**
Monitor 13 inch	Impression	cm1448mk	?	ON	100%	50%	NA	**61**	**46.2**	**76%**

Most power supplies are even less efficient when operated at partial load than they are at full load. Transformers, for example, will produce heat and waste power even if there is no low voltage load connected to their output. Voltage regulators -- sometimes found in the power supply itself or in the load connected to it – add to the problem.[13] Because household voltage can routinely vary from 105 to 125 volts AC, and because the load itself varies over time, a power supply needs a regulator to provide relatively constant voltage for some sensitive electronic

[13] More efficient designs are available, including so-called "low dropout voltage regulators." See International Energy Agency, *Things That Go Blip in the Night: Standby Power and How to Limit It*, 2001, p. 23.

equipment.[14] Voltage regulators can decrease the efficiency of the power supply even more, automatically compensating for momentary drops in demand by increasing internal power consumption.[15]

Standby Losses

The extreme case of low part-load efficiency is standby losses, widely publicized as "vampires" or "leaking electricity" because of a recent Executive Order and proposed federal legislation. When products containing power supplies are left plugged in, but are not in use, they normally consume at least a few watts of power, and sometimes as much as 25 or 30 watts, even when they appear to be switched off. The column in Table 2 entitled "Total Input Watts" for the "Power Off" entries indicate the approximate standby losses that consumers will experience. These losses are very small per product, but add up to sizable waste across billions of connected devices.

Dr. Alan Meier and other researchers at Lawrence Berkeley National Laboratories have already extensively documented these standby losses. Meier believes that U.S. households waste about $3.5 billion worth of electricity annually on standby losses, and that Californians could cut their home electric bills by about 5 to 10% through advanced power supplies that virtually eliminate standby power use.[16] Household surveys conducted by LBNL and other organizations around the world have documented fairly similar standby power loads – about 70 to 125 watts of total power drawn continuously by 20 to 25 products per home. He has proposed a global initiative to reduce standby power consumption for most electrical products to 1 watt or less. That approach has begun to appear in EPA's Energy Star® specifications, starting with "set-top boxes" such as cable TV boxes, satellite receivers, and digital video recorders.[17] See Appendix A for more details.

Ecos Consulting worked with Carrie Webber of Lawrence Berkeley National Laboratories to estimate the total number of devices containing power supplies in use in the U.S. The total represents nearly 2.5 billion products, not including military, aerospace, automotive, and most industrial applications. The products divide into the following groups:

Table 3 – U.S. Estimates for Number of Products in Use that Contain Power Supplies

Product Category	**Number in Use**
Video Products	716 million
Computers & Office Equipment	486 million
Audio Products	390 million
Telecommunications Products	317 million
Appliances and Battery Chargers	252 million
Miscellaneous Products	247 million
Lighting Products	86 million
Total	**2.5 billion**

[14] See Joseph J. Carr, *DC Power Supplies: A Technician's Guide*, Tab Books, 1996, p. 195.
[15] See www.netfront.net/~marco/t6.htm
[16] PR Newswire, "Power Integrations Participates in President George W. Bush's Energy Policy Roundtable," May 29, 2001. See also Richard J. Babyak, "Stand By Me (Efficiently)," *Appliance*, July 2000.
[17] Diane Richey, "The Power of 'Off'," *Appliance Magazine*, June 2000, p. 11; and http://eetd.lbl.gov/leaking.

We estimated power consumption by each product in active, sleep (where appropriate), and standby modes and the approximate amount of time each product spends in each mode.

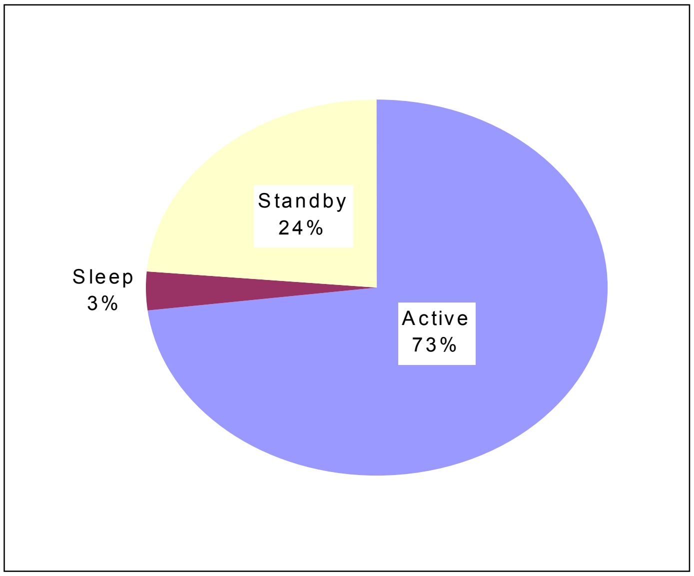
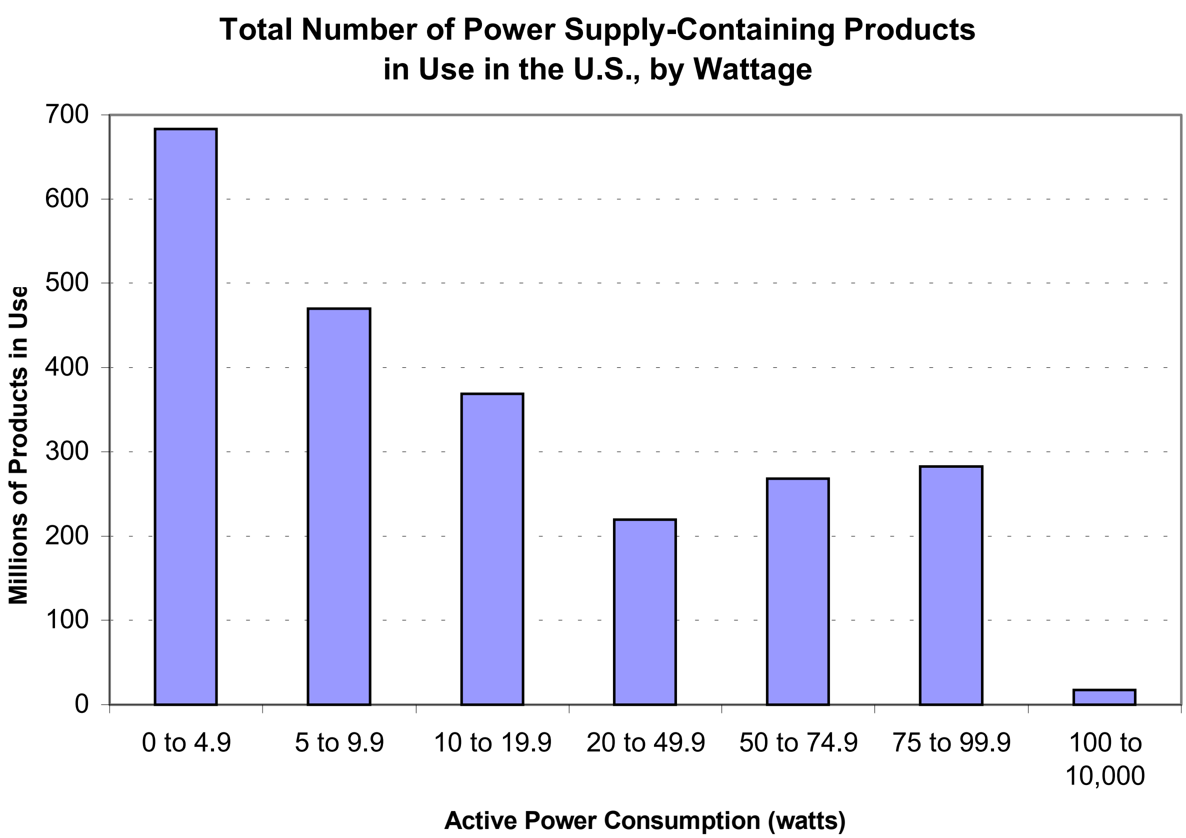


Figure 3 – Energy Consumption by Operating Mode

Active mode consumption turned out to be the most significant by far, at 73% of the total. This is a surprising finding, given the significant attention that has been paid to the standby power issue so far and the fact that most power supplies are sold for low wattage applications. It also suggests a major opportunity to capture energy savings by expanding the focus of Energy Star labeling programs (Appendix A) and the recent Executive Order to encourage greater active mode efficiency.

Our research and market estimates provided by Power Integrations both suggest that the majority of power supplies sold today (both external and internal) are for applications that consume less than 20 watts each in active mode (Figure 4).

Figure 4



It turns out that a relatively small number of individual product types account for a large share of the total energy use. In those products, not surprisingly, active power consumption is dominant, as can be seen in Table 4.

Table 4 – Estimated Electricity Use (Per Unit and Total) for the Most Significant Power Supply-Containing Products

Product	# in Use	Active kwh/year	Sleep kwh/year	Standby kwh/year	Total kwh/year	Total twh/year
Analog TV	250,000,000	105.1		33.8	139.0	34.7
Desktop Computer (C/I)	94,000,000	296.1	18	6.6	321.0	30.2
Computer Monitor (C/I)	94,000,000	205.0	20	2.2	227.7	21.4
Minicomputers	2,000,000	3,854.4			3,854.4	11.8
Uninterruptible Power Supply	29,500,000	314.8			314.8	9.3
VCR	150,000,000	6.0		49.6	55.6	8.3
Desktop Computer (Res)	75,000,000	79.7	4	16.0	99.7	7.5
Computer Monitor (Res)	75,000,000	56.9	4	29.1	89.7	6.7
Mainframe Computer	110,000	38,544.0			38,544.0	6.4
Stereo Component	75,000,000	73.2		9.2	82.5	6.2
Cordless Phone	128,400,000	31.3		12.0	43.3	5.6

National Energy Consumption and Environmental Implications of Improved Power Supplies

In total, more than 6% of national electricity consumption passes through power supplies – some 217 billion kwh of electricity per year worth about $17 billion.

To estimate the national potential for energy savings from more efficient power supplies, we can consider three simultaneous goals:

- Replace all linear power supplies currently in use (average efficiency of about 40 to 50%) with advanced switching designs (average efficiency of about 80 to 90%)
- Replace all 70% efficient switching power supplies with advanced switching units with an efficiency of 80% or more
- Reduce standby power consumption of most power supplies to 1 watt or less.

By our estimates,[18] the annual energy savings from the first two measures alone would be more than 1% of total U.S. electricity use: about 32 billion kwh and reductions in national energy bills of at least $2.5 billion per year. The majority of these savings would come from targeting the least efficient models (see Appendix B). The environmental dimensions of these savings are also enormous – about 24 million tons of carbon dioxide emissions per year, with proportionate reductions in the emissions of other key pollutants including NOx, SO2, particulates and mercury. This represents about 0.4% of all U.S. carbon dioxide emissions, or about 6% of the reductions

[18] Sources include: Kaoru Kawamoto, Jonathan G. Koomey, Bruce Nordman, Richard E. Brown, Mary Ann Piette, and Alan K. Meier, *Electricity Used by Office Equipment and Network Equipment in the U.S.*, LBNL-45917, August 2000; http://www.eia.doe.gov/emeu/cbecs/char99/prelim1.htm#Table%2012; Karen Rosen and Alan Meier, "Energy Use of U.S. Consumer Electronics at the End of the 20th Century," in *Proceedings of The Second International Conference on Energy Efficiency in Household Appliances*, Naples, Italy, September 2000; *Appliance,* "Statistical Review: 47th Annual Report – A Ten Year Review 1990-1999 of the U.S. Appliance Industry," May 2000; Energy Information Administration, *A Look at Residential Energy Consumption in 1997,* 2000, p. 80; eBrain Market Research, "U.S. Factory Sales of Consumer Electronics," *Consumer Electronics Data Book*, Consumer Electronics Association, 2000.

the U.S. would need to achieve to comply with the Kyoto Protocol. Indeed, this amount of energy savings is equivalent to the annual output of about seven large nuclear or coal-fired power plants, or the annual electricity use of more than 3.5 million homes.

The additional impacts of reducing standby consumption are difficult to estimate. Though probably smaller than the active mode savings, they might in some cases be easier to achieve.[19]

How Can Power Supply Efficiency Be Improved?

There are three main design approaches to reducing standby power consumption. The first places a power switch in front of the power supply to shut down the entire circuit when the product is not in use. This only works with internal power supplies, since external power supplies are connected in front of any power switches. It reduces standby consumption, but does not improve active mode efficiency.[20]

The second approach is to employ one power supply for the primary load and a second, smaller power supply for any needed standby loads, such as operating a remote control detection circuit or maintaining operation of a small display. The original, main power supply is unchanged, but the second power supply is optimized for a much lower load. This approach cuts standby losses, but does not improve active mode efficiency.

The third approach is to use a single power supply, but employ "pulse width modulation" (PWM). In these designs, power is delivered at the appropriate voltage (or voltages) in a rapid series of very brief pulses.[21] The power supply is designed to utilize only the number of pulses needed to meet the demands of the load. So, in standby mode, the majority of pulses would be skipped by the power supply, allowing it to operate efficiently across a wide range of power outputs. Similarly, other designs simply shut off for brief periods when no power is needed, again increasing part-load efficiency.[22]

So the switching or PWM approach can save energy across the full range of load conditions, and is therefore preferable from an energy savings standpoint to the other approaches that focus on standby power use only. Likewise, even more efficient alternatives to PWM are available, including what the *Power Supply Cookbook* refers to as "resonant transition" or "quasi-resonant" switching regulators. These may require more design time and initial expense than linear or standard PWM power supplies, but they maximize energy efficiency (attaining full load efficiencies of greater than 90%) and also reduce radio frequency interference.[23]

The overall differences in power use between an inefficient linear design and a highly efficient power supply can be seen in Figure 5. It illustrates the difference in efficiency between two cordless telephone power supplies. The shaded area between the input and output power lines represents power wasted within each power supply as heat. The most efficient designs not only draw very little power in the no load condition, but waste very little extra power as heat when

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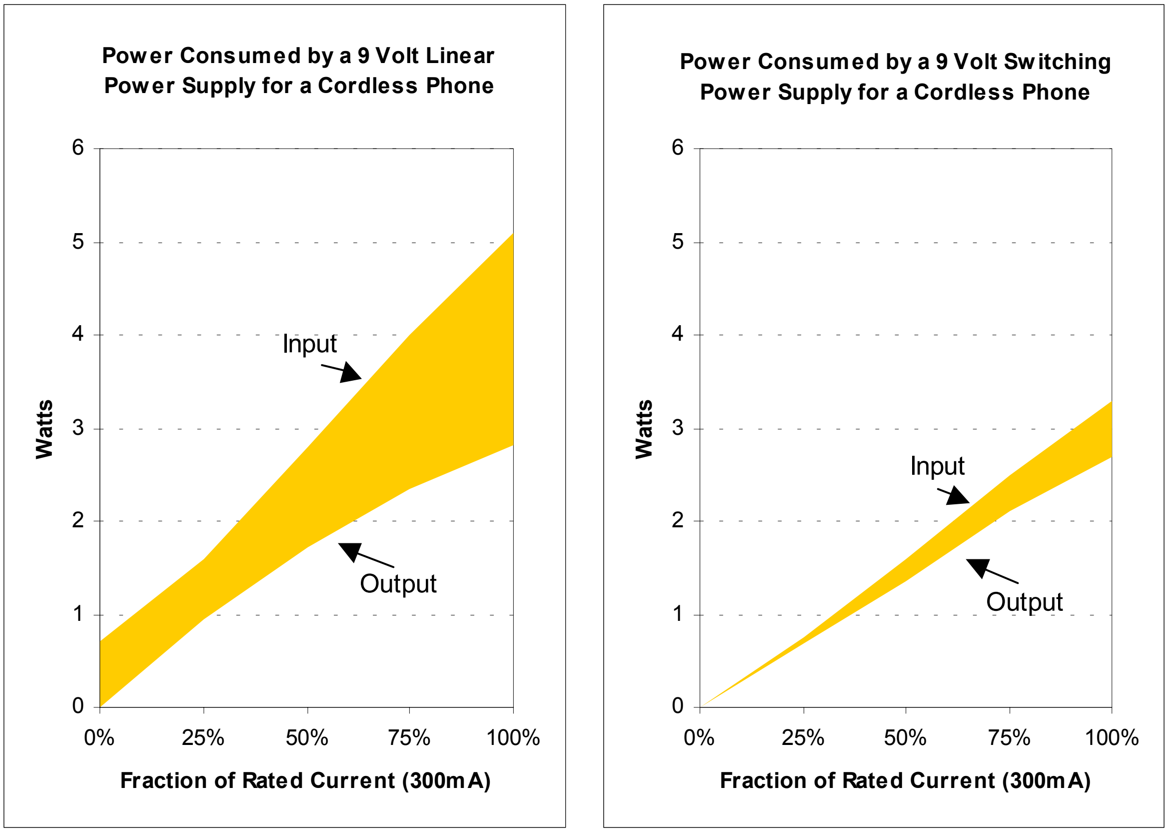
[19] Personal communication, Tom Radley, Hewlett Packard, January 14, 2002.
[20] For more information, see International Energy Agency, *Things That Go Blip in the Night: Standby Power and How to Limit It*, 2001, pp. 20-22.
[21] Unlike linear power supplies, which only provide output at a single voltage, the various types of switching power supplies can provide multiple voltage outputs simultaneously. Doing so with linear power supplies would require multiple supplies, each of which would add to cost and reduce efficiency.
[22] Power Integrations, *TNY264/266-68, TinySwitch II Family: Enhanced, Energy Efficient, Low Power Off-Line Switcher*, March 2001, pp. 1-5.
[23] Marty Brown, *Power Supply Cookbook*, 2nd Ed., Butterworth-Heinemann, 2001, pp.1-10.

output levels rise. Note that both designs provide a little less than 3 watts of output at maximum load, but the efficient product draws about 3.2 watts to meet that need, compared to more than 5 watts for the inefficient product.

Figure 5 – Comparing Linear and Switching Power Supplies



The point is that actions taken to reduce standby power consumption will not always reduce active mode consumption unless a conscious design decision is made to achieve both. On the other hand, inherently efficient switching power supply designs could save energy in all of a product's operating modes.

There are other, related ways to save energy as well, through more intelligent design. Internal power supplies, such as those found in computers, routinely require one or more fans to exhaust the heat created by the power supply from the case. These fans contribute additional electric loads and operating noise. The latest personal computers contain as many as five cooling fans (power supply, case, microprocessor, bridge chip, and video card), and each puts additional load on the power supply. As computer processor speeds and power levels increase, this problem of heat build-up will compound, increasing the desirability of more efficient power supplies.[24]

At the same time, advances in software and chip design have the potential to reduce computer power consumption significantly. Microsoft's new XP operating system offers the potential to cut power use by up to 40%, simply by telling the microprocessor to operate more slowly when the demand for system resources is low.

[24] Elizabeth Corcoran, "Too Hot to Handle," *Forbes*, April 2, 2001, pp.126-128.

Intel has worked with partners Hewlett Packard and Legend to design new "Concept PC's" that are optimized for small size and quiet operation. These products often require only one or two fans to deliver very high performance, simply by rearranging components to facilitate better airflow, reducing power supply loads, and employing more efficient microprocessor designs.[25]

Other very intensive computing applications like "server farms" have already migrated to highly efficient power supplies in many cases, because the individual servers are placed so close to each other in vertical racks that little space is available for heat sinks, large cooling fans, or other means of carrying away waste heat. In addition, air conditioning and ultra-high reliability power costs for such buildings can be so high that it is cost effective to incorporate very highly efficient power supply designs in as many of the servers as possible. Apple Computer also faced substantial space constraints in the design of its latest iMac desktop products, and incorporated an 85%+ efficient power supply to minimize heat buildup in that confined space.[26] As a result, it seems clear that the challenge for improving mainstream consumer electronics' power supply efficiency is less about inventing new technologies than it is about diffusing and accelerating the adoption of good designs already in use in niche markets.

Laptop computers traditionally employ external switching power supplies, which can keep themselves cool without need for active ventilation. This prevents the power supply's heat from contributing to the ventilation load for the computer and vice versa, saving energy, battery life, and weight. Many LCD computer monitors employ a similar design approach for similar reasons. However, there are key disadvantages to this approach as well. LCD screens are backlit by very thin compact fluorescent lamps, which require AC power to operate. Because external power supplies convert all incoming AC power to DC, much of that power must then run through an inverter to be turned *back* into AC before being routed to the fluorescent lamps. More efficiency losses occur in the inverter, so it is not surprising that about two-thirds of the total power use in an LCD display occurs in the backlights and associated circuitry.

How Much Does It Cost to Make Power Supplies More Efficient?

Since the energy savings are so compelling, the obvious question to ask is, what are the incremental costs needed to achieve these energy savings? After interviewing a number of manufacturers of highly efficient power supplies, we believe the incremental costs are about 30% for power supplies up to 10 watts output, about 20% for units in the 10 to 20 watt range, and 10% or less for somewhat higher wattage models.[27]

As a result, linear power supplies are relatively uncommon in rated outputs greater than about 40 or 50 watts, where their weight, size, and inefficiency not only lead to higher operating costs, but can even lead to higher installed costs (purchase price plus installation cost). This phenomenon is illustrated conceptually in Figure 6, which shows that the incremental cost of a switching power supply relative to a linear design tends to decrease as output wattage rises. Eventually, at high enough wattages, linear power supplies may actually be a more costly option.

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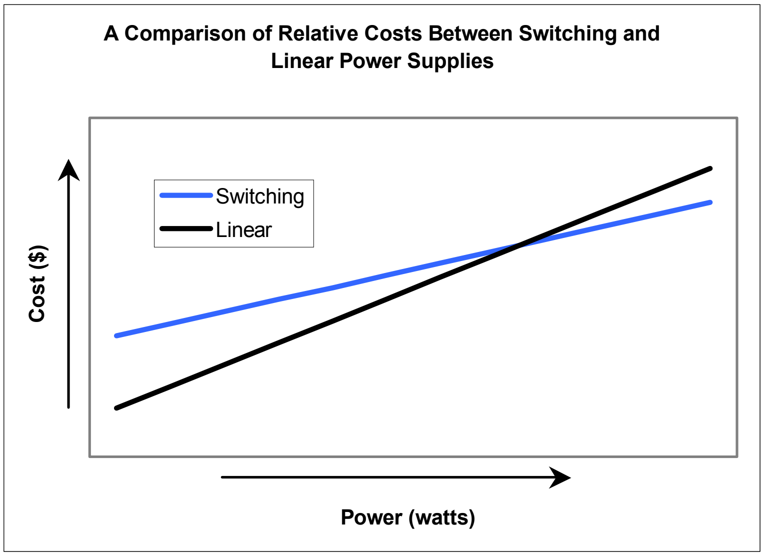
[25] Personal communication, Henry Schaechterle, Engineering Manager, Advanced Desktop Platforms, Intel Corporation, November 2001. See also http://developer.intel.com/technology/easeofuse/conceptpc.htm and Henry Norr, "Power-Miser Microchips Generous to Handheld Devices," *San Francisco Chronicle,* August 24, 2000.

[26] Personal communication, Gus Pabon, Manager, OEM Power Design, Apple Computer, January 14, 2002.

[27] Personal communication, Steve Nolan and Michael Archer, Celetron, March 2002.

Figure 6



For external power supplies specifically, we estimate incremental costs of roughly $1.00 per unit at the manufacturer level, though actual costs can be as low as $0.25 to $0.30 in some applications.[28] The least expensive external power supplies wholesale between $1.00 and $7.00, suggesting a cost premium of about 4 to 30%. In fact, many equivalently sized external power supplies sell for virtually identical prices, regardless of whether they employ linear or switching technology.[29] Overall, it appears that energy savings will pay for themselves in a few months to a year in most cases with efficient external power supplies, yielding net lifetime savings of more than $1 to more than $11 per unit over their lifetimes.

The incremental cost of more efficient internal power supplies is more difficult to determine. Computer power supplies normally sell for a wholesale price of about $0.08/peak watt in large quantities.[30] So the 200 watt power supplies typically found in computers represent about $16 of the cost of a product that might retail for $1,000 or more. Virtually all computer power supplies are designed to operate at an efficiency of about 70% in peak load conditions (see Figure 7). Very few computers actually include enough peripherals and components to reach peak load, so actual operating efficiencies are somewhat lower.[31] In addition, the power they supply to microprocessors (often 30 watts or more), must pass through a second DC-to-DC converter, where another 20% of the remaining power can be lost to heat. Computer power supply designs that improve efficiency across a wide range of loads would generate sizable savings. They could be highly cost effective, even if incremental costs were $15 to $30, but more data are needed to answer this question with certainty.

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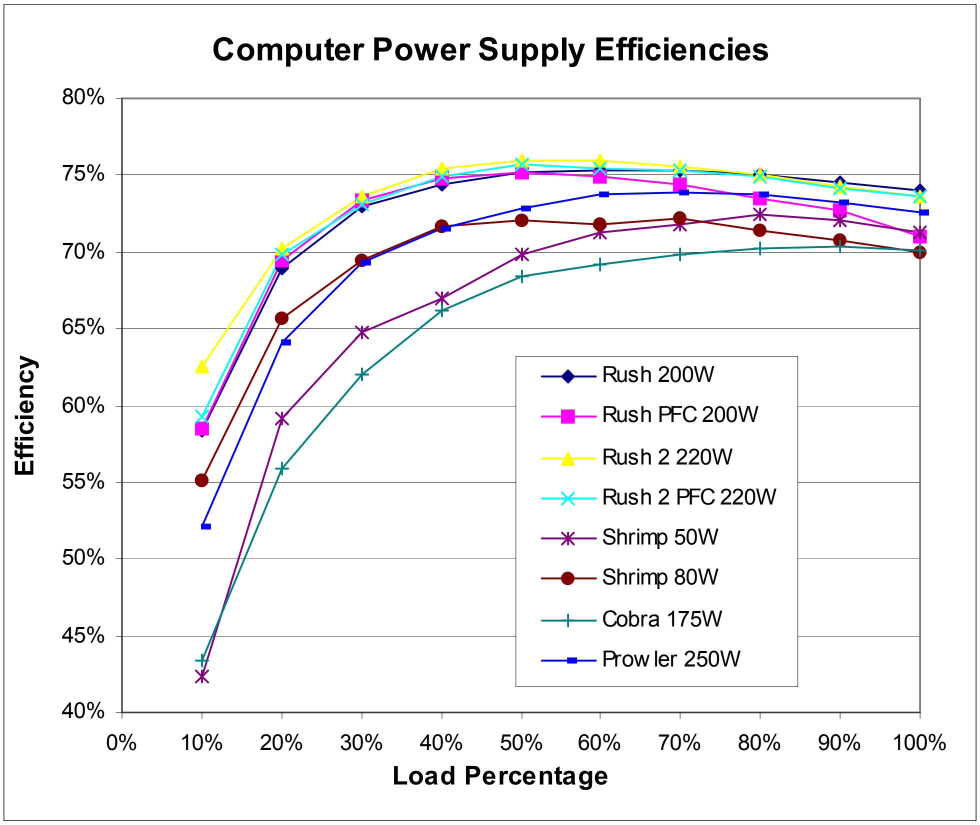
[28] Personal Communication, Balu Balakrishnan, VP of Engineering and Strategic Marketing, Power Integrations, May 2001.
[29] Hosfelt Electronics, Inc (Compare #56-845 and #56-615 with the same outputs and price but one switching and one a transformer), 2001-A
[30] Personal communication, Sat Narayanan, Sales Manager, Delta Power Supplies, November 13, 2001.
[31] This is estimated instead of measured, because computer power supplies have multiple voltage outputs and are more difficult to "load" and measure precisely than single output power supplies. If a high-end PC with a 300 watt (rated output) power supply is drawing 100 AC watts and has a part-load efficiency of 65%, the actual DC load is only 65 watts. That means the power supply is operating at only 21% of its rated output.

Figure 7 – Power Supply Efficiency Data from Compaq



When other factors are considered such as savings in shipping weight, reliability, and convenience, the difference in initial cost becomes negligible, and the energy savings could be considered a bonus. How much would consumers pay to have all of the outlets readily, safely available on their power strips, instead of having many of them blocked (Figure 8) by bulky external power supplies? In fact, Cliff Walker, the Vice President of Corporate Development at Power Integrations, believes that utility financial incentives may not be needed to help more efficient designs succeed. With the right marketing and education, he feels that the overall benefits of the more efficient designs are compelling on their own, and clearly justify the modest incremental cost of the products.[32]

There needs to be a much greater emphasis given to the non-energy benefits of more efficient power supplies. While the reduced weight and physical size have already proven to be valuable for portable electronic products and battery chargers, they have not yet been fully exploited for other products. How much is it worth to increase the number of products that can fit into a standard shipping container and the corresponding weight of products that can be loaded onto a truck? Power Integrations has begun to explore those issues[33] in its marketing, but more can and should be done to understand the market value of those benefits. The benefits would likely carry

[32] Personal communication, Cliff Walker, Power Integrations, April 2001.
[33] See, for example, Bob Frizzell and Brooks Leman, *Switch Mode Power Supply Adapters for Portable Applications*, Power Integrations Inc., pp. 2-3; and Mohamed Darwish, *Role of Semiconductor Devices in Portable Electronics Power Management,* Power Integrations Inc., p. 1.

all the way through the products' lifecycle, resulting in lower transport and disposal costs and environmental impacts as well.

Likewise, highly integrated power supply designs also greatly reduce the number of discrete components needed on a circuit board. Power Integrations claims that its "TOPSwitch" product can reduce power supply part count from the 40 to 80 components found in typical designs to as far as 12 components.[34] This would likely translate to increased reliability and ruggedness, while simplifying design time, troubleshooting, and repair.

In general, manufacturers are already redesigning products to meet a variety of different national and international standards for standby power consumption, harmonics, power factor, and even active power consumption in some cases.[35] Including efficient power supplies that meet a wide range of those needs at once will likely prove more cost effective than redesigning for each incremental objective over time.

Figure 8 – The Real Reason External Power Supplies Are Known as "Wall Warts"

In general, OEM price differences of only pennies per unit, which might seem trivial from a societal or utility perspective, can be deal-breakers to power supply manufacturers, who work in highly competitive markets. As a result, we assume that some of the advanced products will continue to sell primarily on the basis of non-energy benefits, while others will need assistance

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[34] Bob Frizzell and Brooks Leman, *Switch Mode Power Supply Adapters for Portable Applications*, Power Integrations Inc., pp. 3-4.

[35] See International Energy Agency, *Things That Go Blip in the Night: Standby Power and How to Limit It*, 2001; European Commission, *Code of Conduct on Efficiency of External Power Supplies*, Brussels, June 15, 2000; www.iea.org/standby/ecpaper.htm; www.efficient-appliances.org; and "TVs: still a big turn on!, *Appliance Efficiency*, 2/99, pp. 6-9.

from voluntary labeling programs, utility incentive and marketing programs, and government standards to gain market share.

There are two prominent reasons why high efficiency power supplies do not occupy a greater share of the power supply market: (1) To consumers, the power supply is inconsequential, many people could not correctly identify a power supply let alone distinguish between a high and a low efficiency unit, (2) more importantly, consumers purchase a complete product not a power supply separate from a product. The OEM purchases the power supply (see Figure 9) some time before assembling the finished product, and the consumer exerts no influence over the selection. Interviews with OEM specifiers and power supply manufactures confirm that energy savings for the consumer are not even considered when choosing a power supply.

Policy Options and Recommendations for Future Work

Our research to date suggests that power supplies represent a surprisingly large electricity use and a very promising opportunity for energy savings. There are a number of market failures and barriers that explain why current power supplies are often so inefficient:

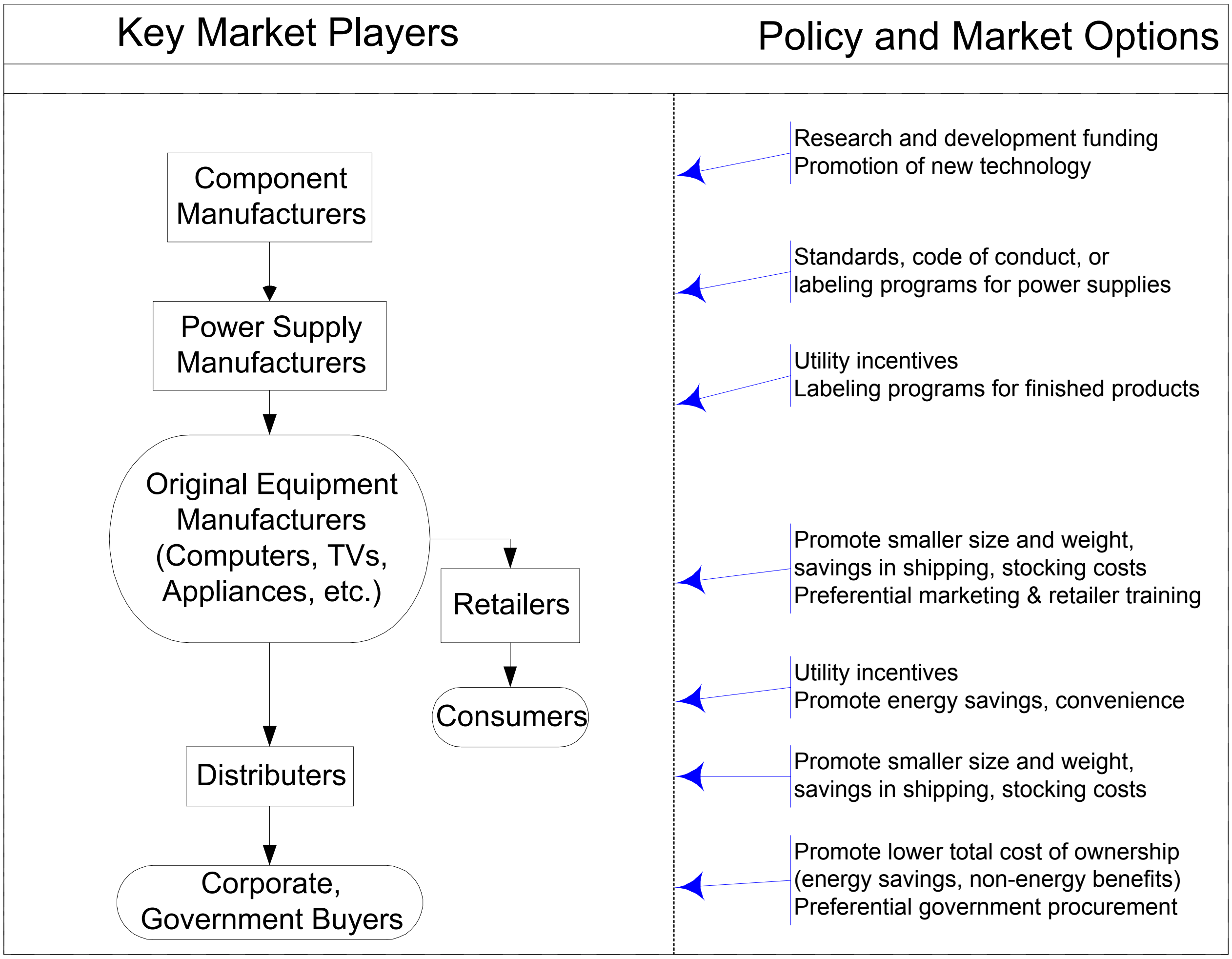
- Power supplies are an obscure component within a larger product. Consumers may understand the overall performance of the product, but are not likely to know anything about the power supply performance itself, or even what a power supply is. There is usually no visible labeling of internal power supplies, and external power supplies are labeled only for maximum power draw and maximum current provided at a given voltage. They do not bear percentage efficiency labels, so consumers have no basis for choosing one over the other.

- To the extent any consumer information about power supplies is disclosed by manufacturers, as in the case of computers, higher wattage capacity is often perceived to be desirable, even if it may reduce the computer's operating efficiency. OEM specifiers often do the same thing, oversizing power supplies to reduce any potential liability or performance troubles from overloading them. In addition, many external power supplies sold today in retail stores are capable of providing any of a number of different voltages, preventing them from being optimized for any one particular application. All of these situations help cause most power supplies to run under part load conditions most of the time, reducing efficiency.

- The electronics market is highly competitive. The products that come with power supplies are often sold at low profit levels to the consumer (or provided free with long term usage plans in the case of many wireless and cable devices), making cost of manufacturing critical. As a result, manufacturers often find themselves competing in undifferentiated commodity markets on the basis of price alone, making it difficult for more expensive, efficient designs to gain a market advantage.

- As with many products, there are often split incentives. The entities responsible for choosing specific power supplies are often not responsible for paying the resulting energy bill. In terms of this research, the power supply buyer is actually the product manufacturer who simply incorporates the power supply into their product. Providing efficiency information to the final user, the consumer, the government or corporate purchasing agent, etc. will be key to internalizing an incentive to purchase more efficient products.

Figure 9 – Market Actors and Policy Options (The Expanded "Food Chain")



Overcoming these barriers will require, in part, a better understanding of the various actors in the power supply marketplace and the points of leverage possible with each. As illustrated in Figure 9, there is no shortage of opportunities. We recommend a number of coordinated actions at different points in the marketplace:

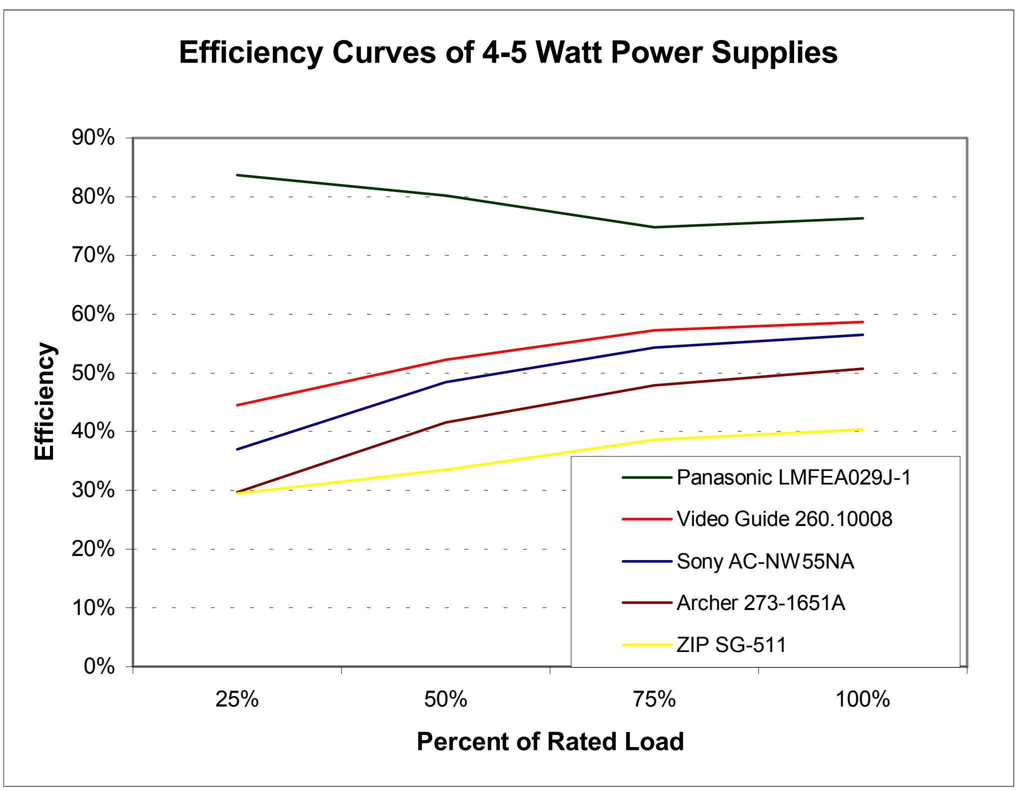
- Further research must be conducted to determine the incremental costs and efficiency gains from advanced power supply technologies, particularly for higher wattage products with internal power supplies.

- Duty cycles and load curves are still poorly understood for the majority of consumer electronics products. This leads to very rough estimates of likely active power savings, and makes it extremely difficult to predict peak load savings, HVAC bonuses, and even total kwh savings with any precision. Utilities and market transformation organizations should sub-meter homes and offices to get a better picture of when power supply-containing devices are being operated and how much power they use.

- More coordination is needed between the various environmental labeling programs, government standards organizations, voluntary industry specifications, and efficiency programs that address consumer electronics and, directly or indirectly, power supply efficiency. There is a global market for the products, so policies enacted in one region alone will be far less effective than coordinated policies enacted simultaneously in North America, Europe, and Asia. High power factor and low total harmonic distortion (THD) are required in some regions, for example, but not in the U.S., causing manufacturers to build two different types of power supplies for those markets. At the same time, coordination between state standards efforts such as the one currently underway at the California Energy Commission and federal activities can greatly increase effectiveness in the market.

- Likewise, international and domestic efforts currently focused only on standby power savings opportunities need to incorporate consideration of active mode savings opportunities as well, which for many products are even higher than standby savings. What may be needed is a new, unified method of testing and reporting efficiency across the full range of operating conditions. These efficiency curves are already occasionally provided by manufacturers in the spec sheets of their products. Government and private procurement officers would benefit greatly from such standardized information (see example in Figure 10 from our measurements) when attempting to select the most efficient products.

Figure 10



- More dialogue is clearly needed between energy efficiency advocates and the manufacturers of power supply components, complete power supplies, and the finished goods that incorporate them. A January 2002 workshop jointly sponsored by PG&E, NRDC, LBNL, and EPA was a useful first step. Subsequent meetings hosted by the Power Sources Manufacturers Association (PSMA), the American Council for an Energy Efficient Economy (ACEEE), and LBNL have led to a number of fruitful follow-up discussions. Ongoing dialogue will help to identify the most effective solutions moving forward.

- EPA and DOE should consider modifying the specifications for their ENERGY STAR labeling programs that address consumer electronics, office equipment, telecommunications equipment, and appliances (see Appendix A) to address standby power consumption, sleep modes (if appropriate), and active mode efficiency. This could either take the form of an established duty cycle and test procedure for each product, or a labeling program for efficient power supplies themselves, to be used by specifiers when purchasing components for finished products. In many cases, the use of an ENERGY STAR-compliant power supply might be the major factor in determining whether the finished product could bear an ENERGY STAR logo.

- An increasing number of appliances now contain power supplies for operating internal controllers, displays, DC motors, etc. At present, the energy efficiency levels of many appliances are measured only when they are performing their intended function (clothes washing, refrigeration, etc.) DOE's test procedures for appliances need to be modified in many cases to capture the power consumed during standby mode by a variety of products, which would provide a more realistic measure of their overall efficiency.

It will clearly be more cost effective to tackle power supply energy efficiency improvements in some products than in others. When focusing on active power efficiency, for example, it makes sense to look first to products that have as many of the following characteristics as possible (with the first two being the most important):

- High active power consumption
- High hours of operation, particularly during peak consumption periods of the day
- Relatively low base case power supply efficiency
- Large sales volumes and installed number of units
- Long life expectancy

It is not always possible to find all five conditions with a particular type of product. CRT computer monitors, for example, have relatively high active power consumption, usage during peak periods, sales volumes, and installed number of units, but have a relatively short life expectancy and moderately high base case power supply efficiency. On balance, they represent a fairly promising efficiency opportunity for better power supplies.

By contrast, VCRs use relatively little power when playing or recording and have very low average hours of operation, so represent a less compelling opportunity for saving active power use through better power supplies, even though they have large sales volumes and installed number of units and a long life expectancy.

After examining a range of different products, we recommend a near-term focus on the following product categories:

- **Computer monitors -** Improving power supply efficiency, increasing sleep mode utilization, and accelerating a market transition from CRT to LCD technology can yield major energy and peak load savings. This is particularly true for monitors used in commercial and institution applications, which tend to have greater hours of use than residential products. See Appendix B for measurements of typical monitor power use.

- **Television sets and projection systems** – As popular television sizes have increased from 20 inch to 27 inch, 32 inch, and even larger sizes, energy use has risen as well. New High Definition TV (HDTV) designs increase power consumption further. The largest plasma and projection models can consume 300 to 750 watts apiece. Major energy savings can be obtained by improving power supply efficiency and promoting energy efficient display types like LCD and DLP instead of CRT and plasma designs.

- **Computers** – Major energy and peak load savings can be obtained by improving power supply efficiency beyond the current 70%, ensuring that power supplies operate efficiently at part load, utilizing improved microprocessor designs and software, enabling effective new sleep modes like Instantly Available PC (IAPC), and using peripheral types like USB and Firewire that can draw their power from the computer's power supply instead of from individual external power supplies. Improved circuit layout and ventilation systems can also reduce power use and noise significantly See Appendix B for measurements of typical computer power use.

- **Battery chargers** – Though power consumption per unit is still far smaller than with the other end uses, sales are growing rapidly. In addition, standard battery technologies like nickel cadmium have serious performance and environmental drawbacks and are often sold with highly inefficient, bulky charger designs. Preliminary measurements by Ecos Consulting indicate that present consumer chargers are often only about 2 to 10% efficient – a remarkably small fraction of the electricity drawn from a wall outlet is actually retrievable for use from the charged batteries. The combination of improved battery technologies like nickel metal hydride and lithium and new charger technologies could yield substantial energy savings, improved performance, longer battery life, and greater convenience. Compared to throwaway batteries, these improved products would cut consumer costs by more than 90% and reduce solid waste impacts significantly.

By focusing on these products first, the market transformation community could gain valuable experience with the costs and benefits of improved power supplies, as well as their performance and longevity. They could also pilot-test market approaches, identifying the strategies that would best serve a broader effort to improve power supply efficiency throughout the economy.

Appendix A: Current Energy Star® Specifications for Products Containing Power Supplies

The federal ENERGY STAR® programs for products that contain power supplies generally follow one of two approaches for securing energy savings. The first approach is to employ a "sleep" mode, powering the device down after a period of inactivity to a mode of operation between active and off, both in function and in power consumption. This leaves the product in a state from which it can be "awakened" rapidly by the user to active mode. This approach depends very much on successful enabling of the sleep feature by the manufacturer, installer, and/or user of the equipment. This has not always been the case with computers and monitors particularly, though recent improvements to hardware and software, combined with outreach to information technology managers and computer users, should substantially increase savings.

The second approach is directed at the family of products that do not off sleep capability, but are either on or off. This approach is designed to limit standby power consumption when the user believes the product is truly off. The allowable standby consumption ranges from 1 to 20 watts across the range of applicable labeled products.

A summary of the current specifications for power-supply-containing products appears in Table 6 below.

Table 6 – Current Energy Star Labeling Requirements for Products Containing Power Supplies

TVs and VCRs	Labeled TVs require 3 watts or less of power when switched off, an energy savings of up to 75% over conventional models, which consume as much as 12 watts while off.
	Labeled VCRs require 4 watts or less of power when switched off, an energy savings of up to 70% over conventional models, which consume as much as 13 watts while switched off.
	Labeled TV/VCR combination units require 6 watts or less of power when switched off, an energy savings of up to 70% over conventional models, which consume as much as 20 watts while off.
Home Audio and DVDs	Labeled Home Audio products consume no more than 2 Watts when switched off. Home audio products include cassette decks, CD players/changers, CD recorders/burners, clock radios, equalizers, laserdisc players, mini- and midi-systems, minidisc players, powered speakers, rack systems, stereo amplifiers/pre-amplifiers, stereo receivers, table radios, and tuners.
	Labeled DVD (digital versatile disk) players consume up to only 3 watts when switched off.
	Starting in 2003, qualified Home Audio and DVD products will consume no more than 1 watt when switched off.
Computers	Labeled products must power down to 15 percent of maximum power usage. For example, a computer that uses a 200-watt power supply powers down to 30 watts or less in the low-power mode.
Monitors	Labeled products must power down to 15 watts or less after 15-30 minutes of inactivity, and then down to 8 watts or less after a cumulative period of 70 minutes of inactivity.
Printers and Fax Machines	Labeled products must power down to 15-45 watts or less depending upon the model's output speed — number of pages produced per minute — after a predetermined period of inactivity set at the factory.
Scanners	Labeled products must power down to 12 watts or less in the low-power mode after 15 minutes of inactivity.
Multifunction Devices	Labeled products must power down to no more than 30-200 watts in sleep mode after 15-120 minutes of inactivity, depending on equipment speed.
Set-Top Boxes	Labeled set-top boxes must consume less than 3-20 watts in stand by or low-power mode. For some satellite systems the manufacturer may add 5 watts per LNB sold with the system.
Telephony	Labeled cordless phones and answering machines must consume less than 3 watts in standby mode and combination cordless phones/answering machines must consume less than 4.5 watts in standby mode.

The obvious opportunity for future energy savings comes largely from including some consideration of active mode or functional efficiency for these products. This is especially important for products in which active power can be relatively high, or products that see heavy usage. The functional definition of efficiency is likely to be different in each case. With TVs and computer monitors, for example it might be inches of screen size or pixels of information per watt. With printers, fax machines, scanners, and copiers it might be pages per kwh.

Appendix B: Understanding Energy Savings Opportunities from Particular Improvements in Power Supply Efficiency

Power supplies are middlemen between the AC power line and the DC product circuitry they are powering. As a result, it requires an AC meter at the wall outlet and a DC meter between the power supply and its final load to calculate overall efficiency. And a particular percentage efficiency improvement in a power supply doesn't necessarily yield a predictable overall power savings. Figure 11 provides a few illustrative examples.

The figure illustrates how many watts of savings result for a given 10 watt (output) power supply from various percentage improvements to its efficiency from various starting points. The starting point turns out to be far more important to the savings opportunity than the percentage improvement. Note, for example, that replacing a 30% efficient power supply with a 50% efficient model would save 13 watts, while replacing a 70% efficient power supply with a 90% efficient model would save only about 3 watts. The implications of this are clear: efficiency policies should focus most heavily on the products with the lowest current efficiency levels – linear power supplies.

Figure 11