Research Findings for Future Computer Energy Efficiency Specifications

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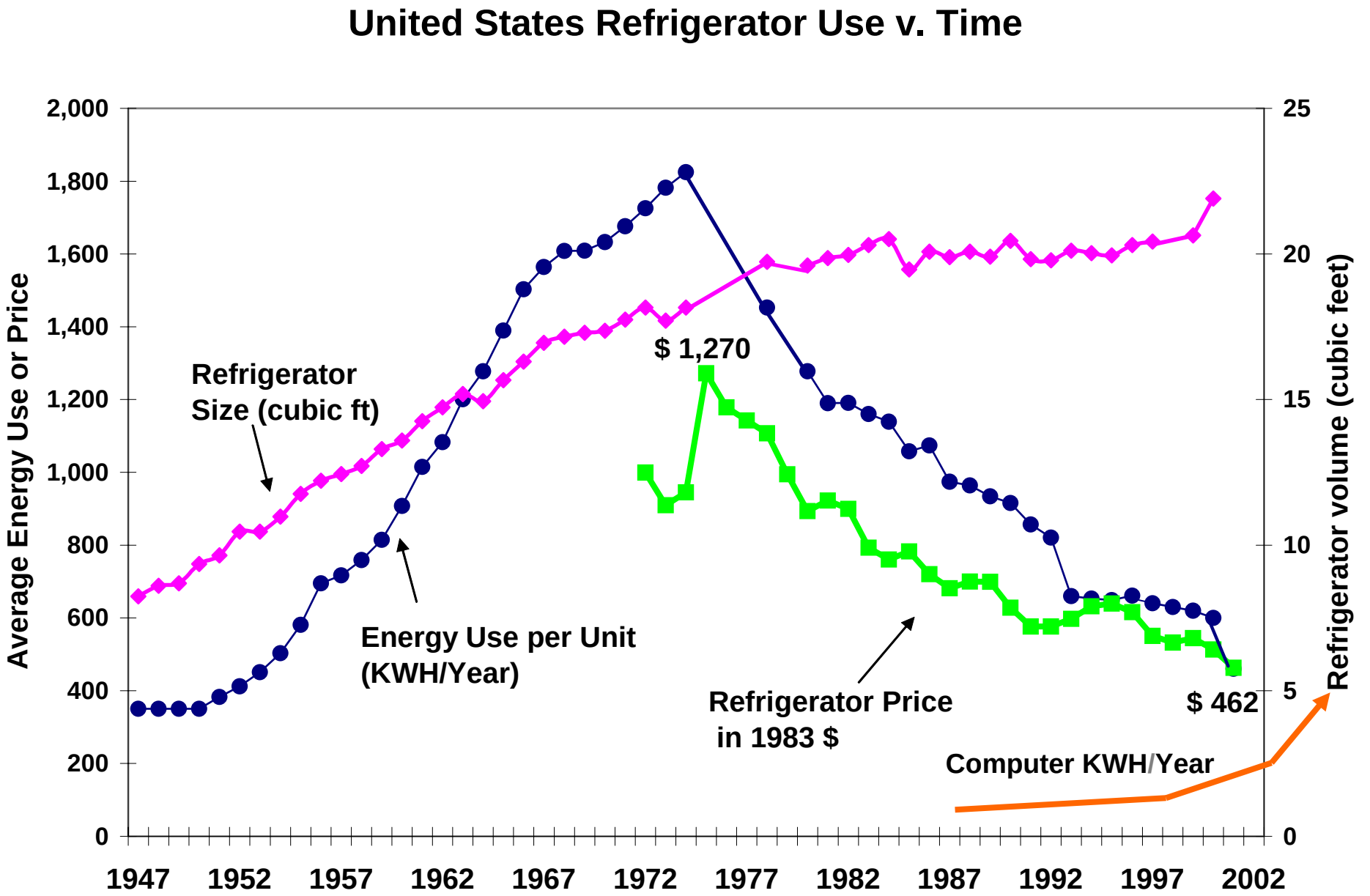
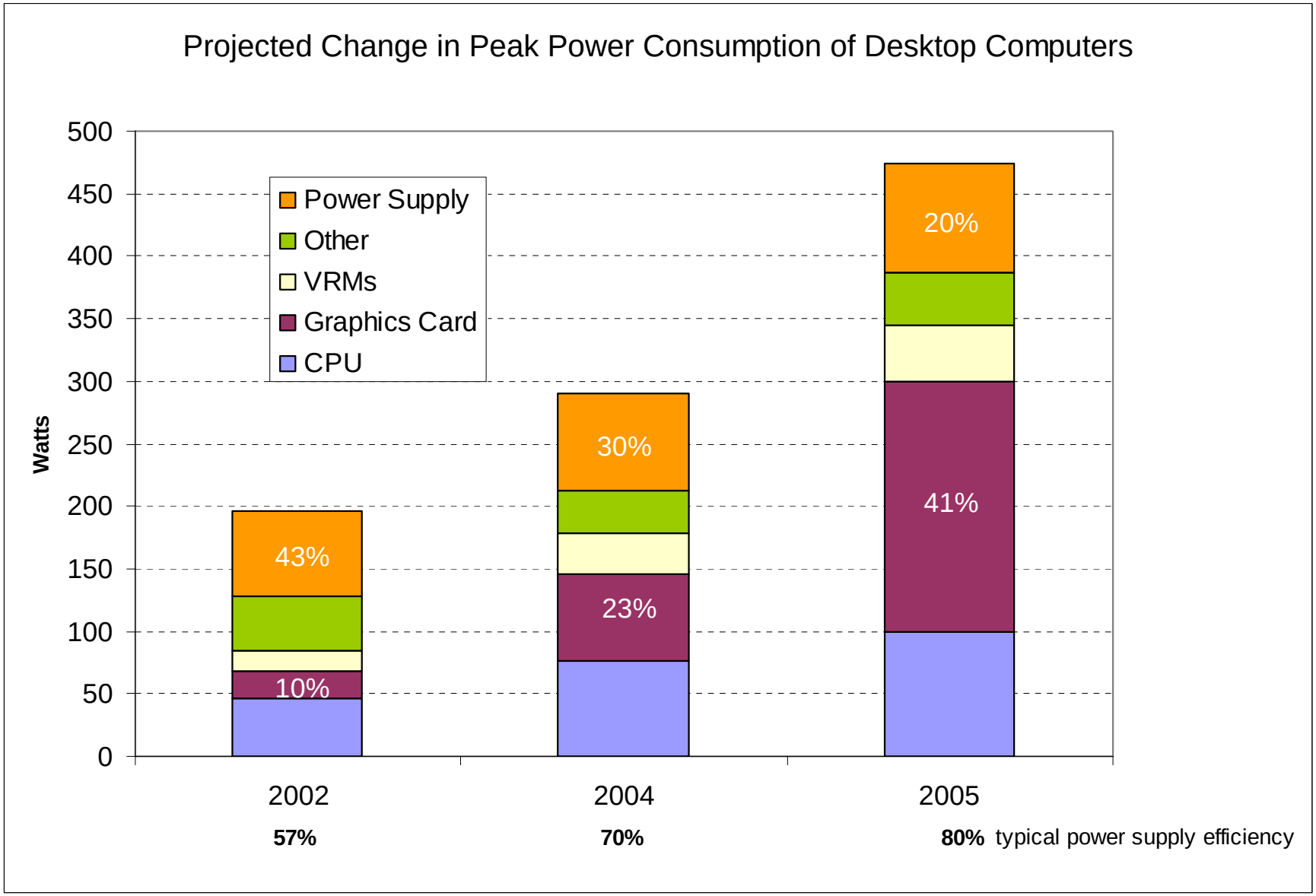
Why go beyond Tier 1?

- Tier 1 does not address networking issues with sleep enabling (LBNL)
- Components other than power supply are not specifically considered in Tier 1
- Capture further energy savings with processors and video cards that scale energy consumption to load profile
- Idle mode currently being considered for Tier 1, but active mode energy use still unchecked
- 2 research avenues: component efficiency and system efficiency


United States Refrigerator Use v. Time
Average Energy Use or Price
Refrigerator volume (cubic feet)
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
25
20
15
10
5
0
1947
1952
1957
1962
1967
1972
1977
1982
1987
1992
1997
2002
Refrigerator
Size (cubic ft)
Energy Use per Unit
(KWH/Year)
$ 1,270
Refrigerator Price
in 1983 $
$ 462
Computer KWH/Year

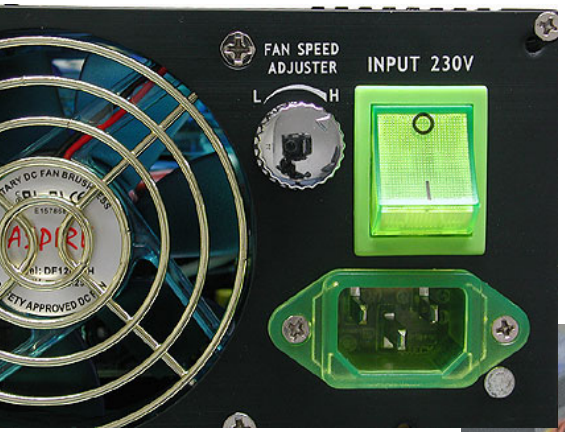
Peak Power of Desktop Computers Rising

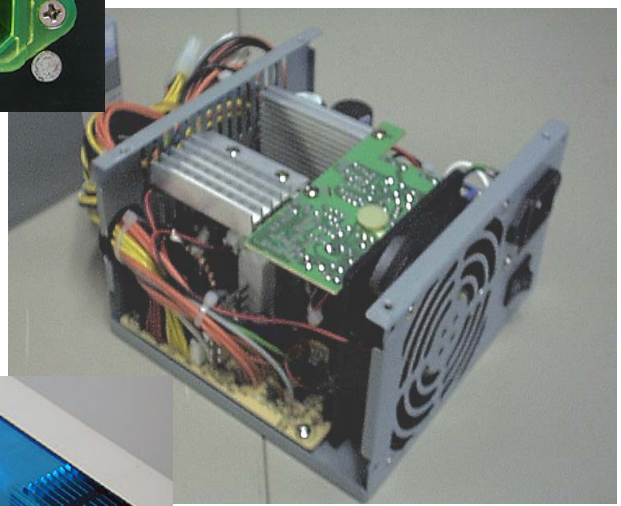


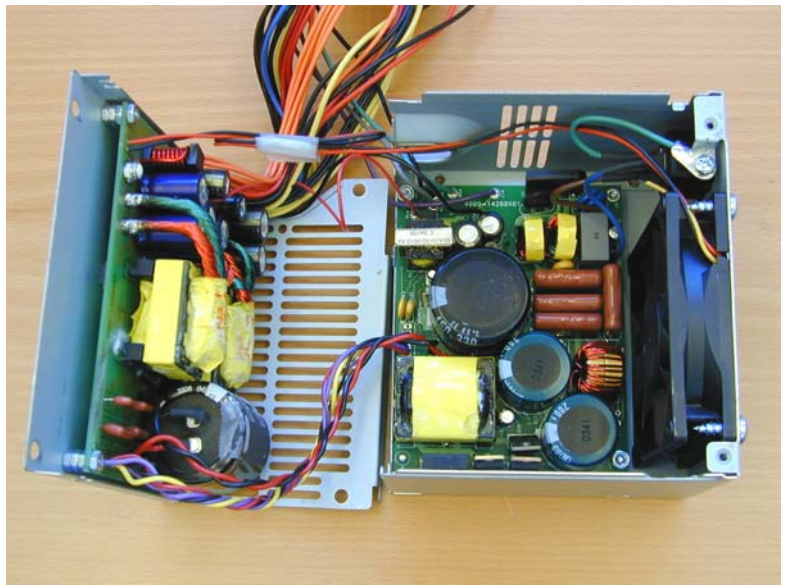
Component Based Approach

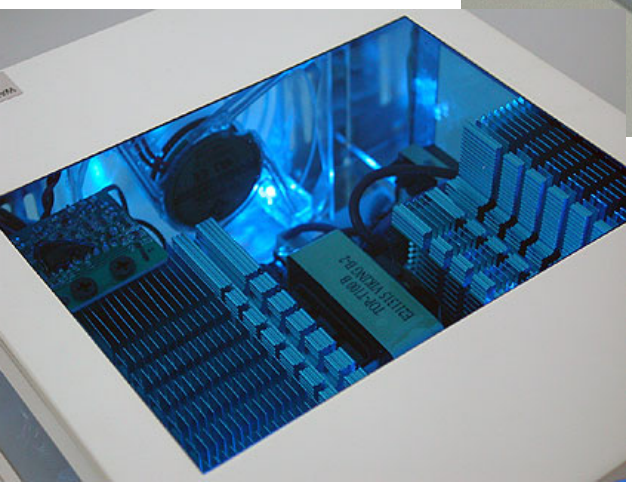
- Set specific hardware requirements on the most energy intensive components including:
  - Power supply efficiency, sizing, and power factor
  - CPU efficiency (CPU capable of multiple lower voltage and frequency combinations that are scaled to load)
  - Video card efficiency (power scaling to load)
  - Cooling system efficiency (liquid cooling or single fan strategies)
  - Memory efficiency (megabytes per dc watt)
  - Software enabling of power management features (no shipping with screen savers)
  - Network power management capabilities
  - DC-DC converter (VRM) efficiency (minimum of X%)

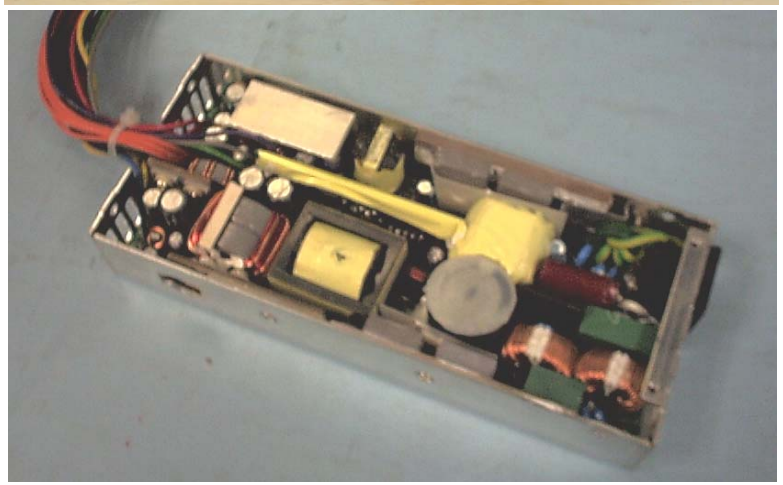
More Efficient Power Supplies Can Be Simpler and More Reliable than Traditional Designs



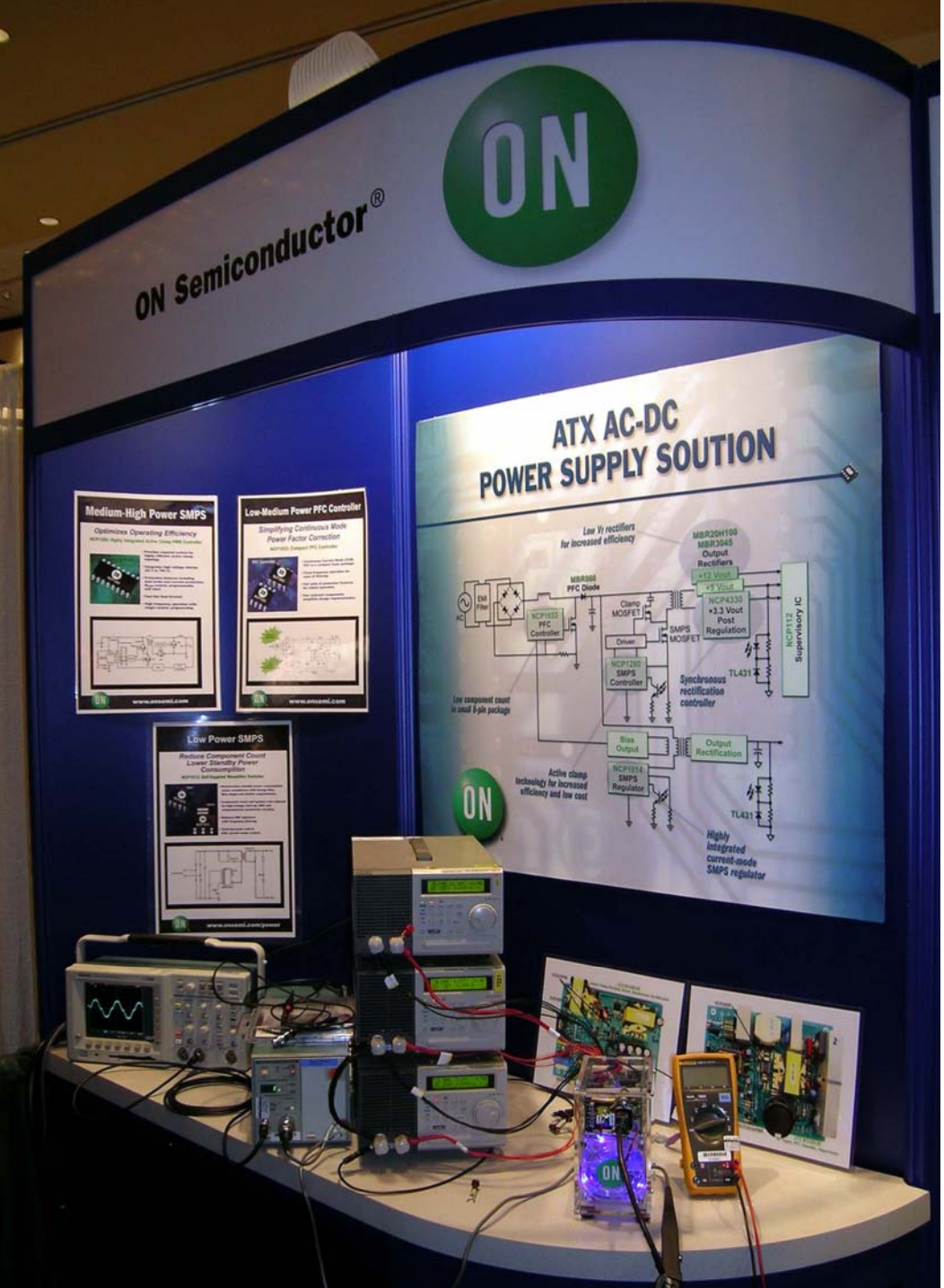


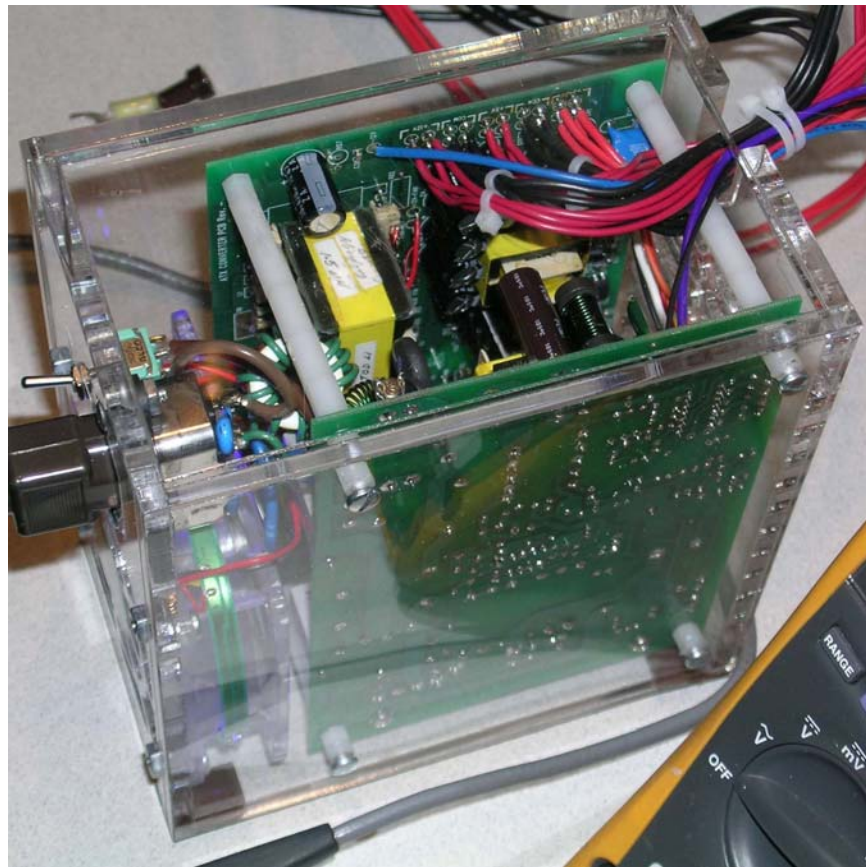




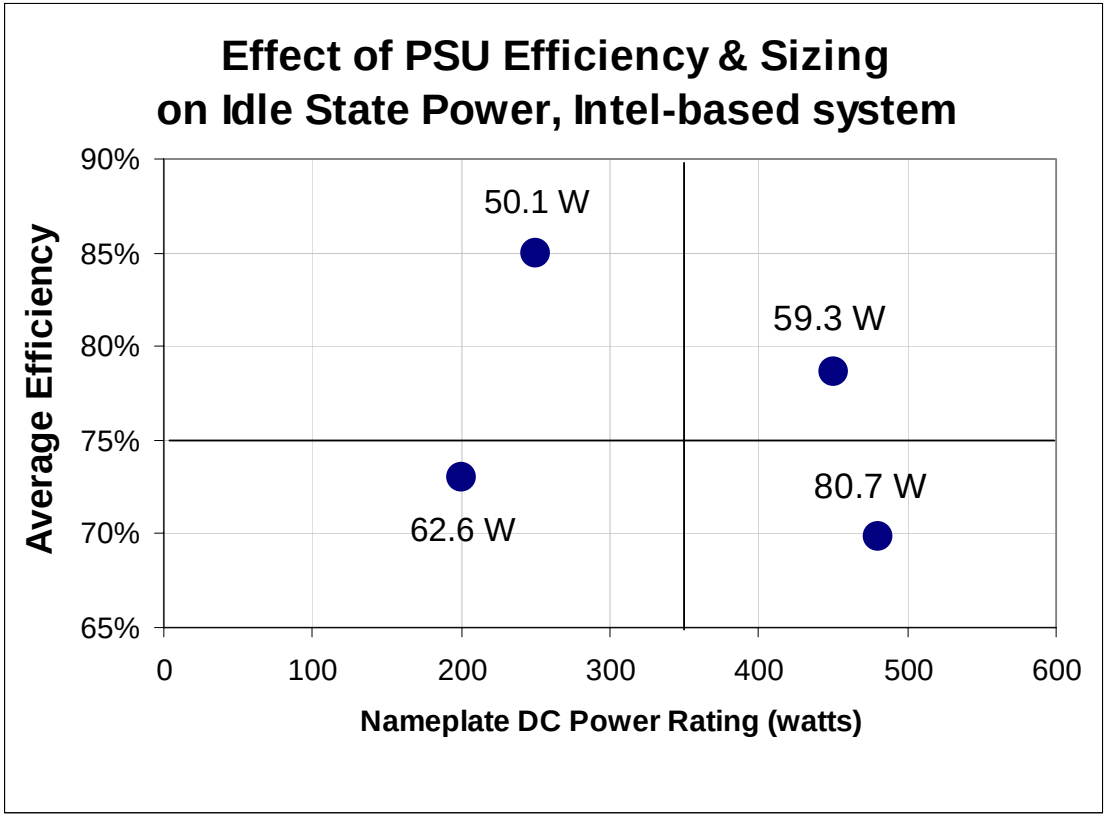


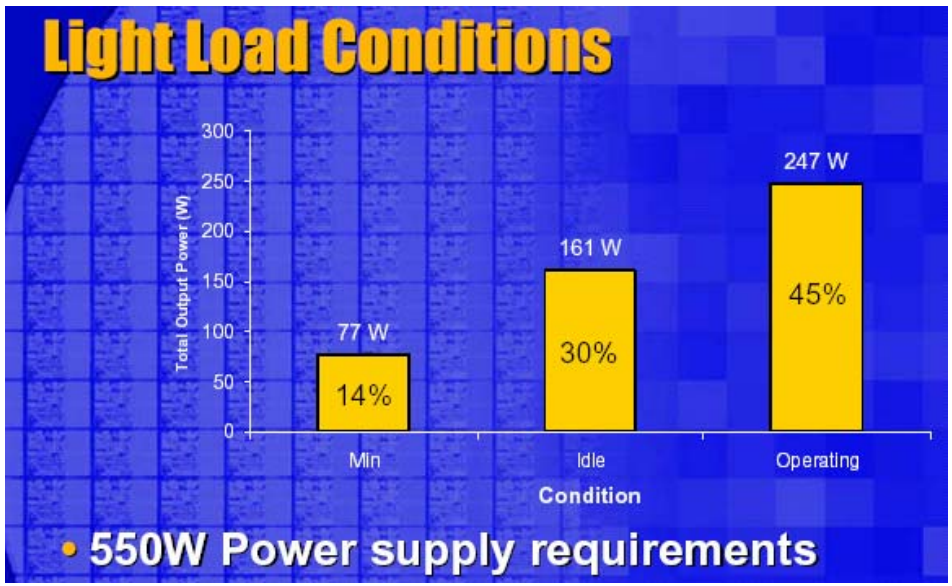
Power Supply Efficiency is a Market Opportunity for Innovative Component Manufacturers

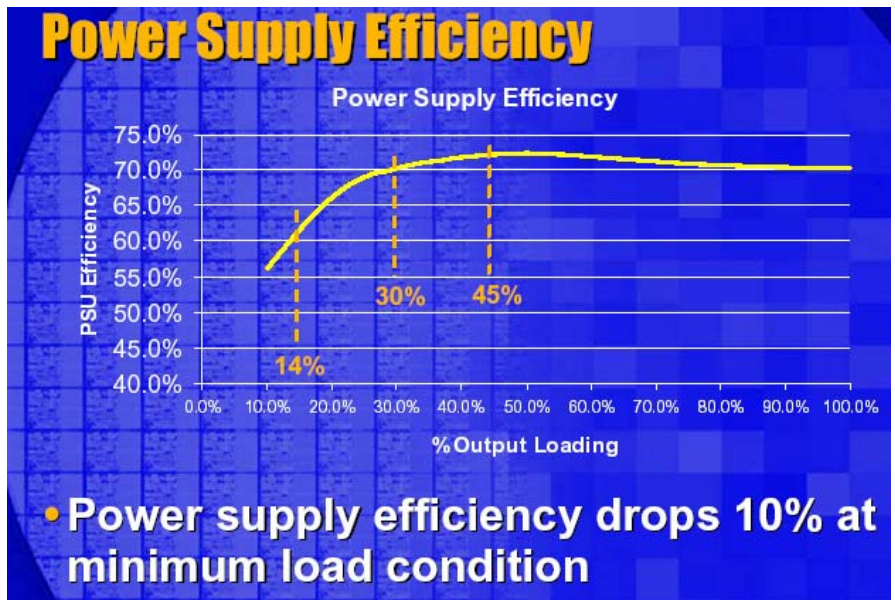




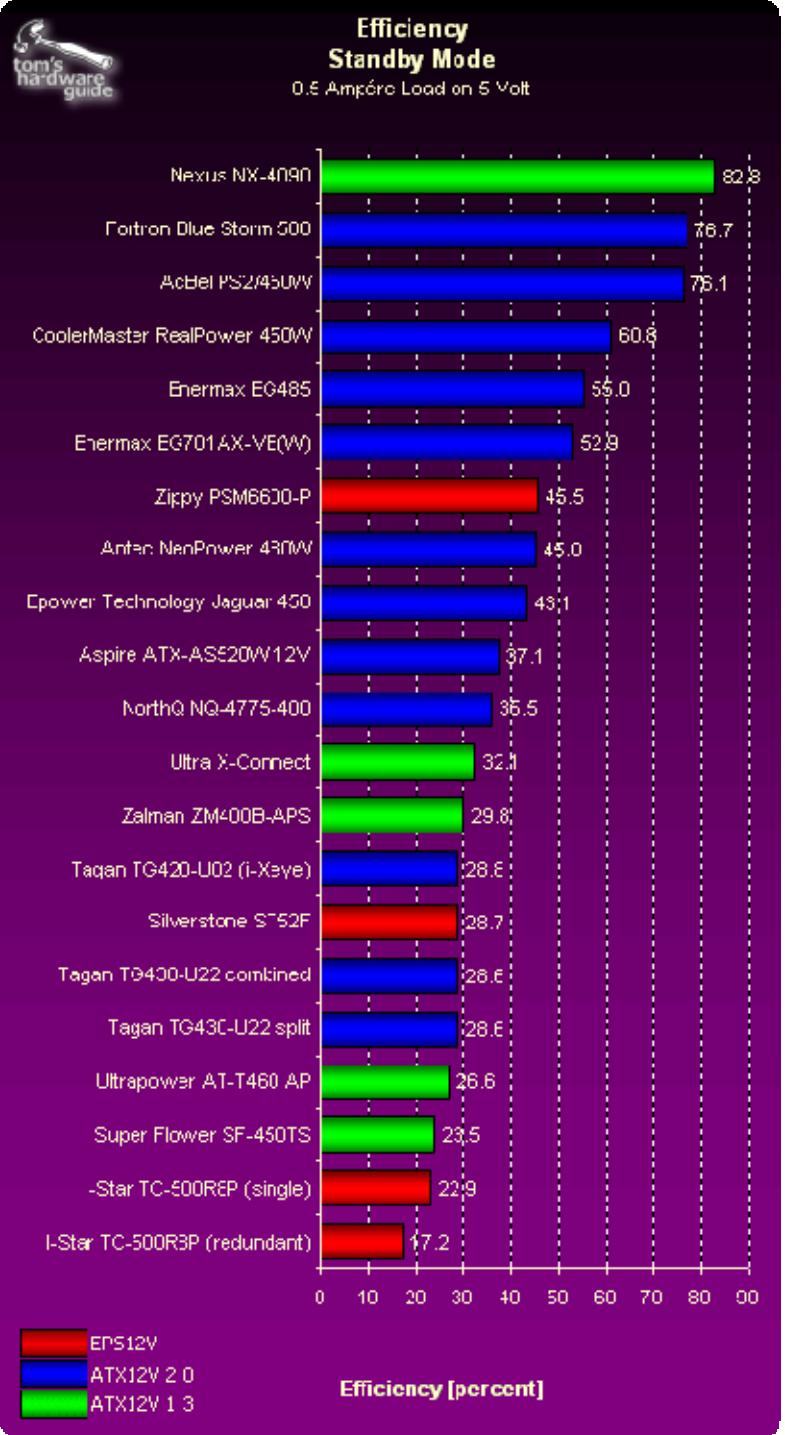
Impact of Power Supply Size on Ac Power Use of Desktops and Servers

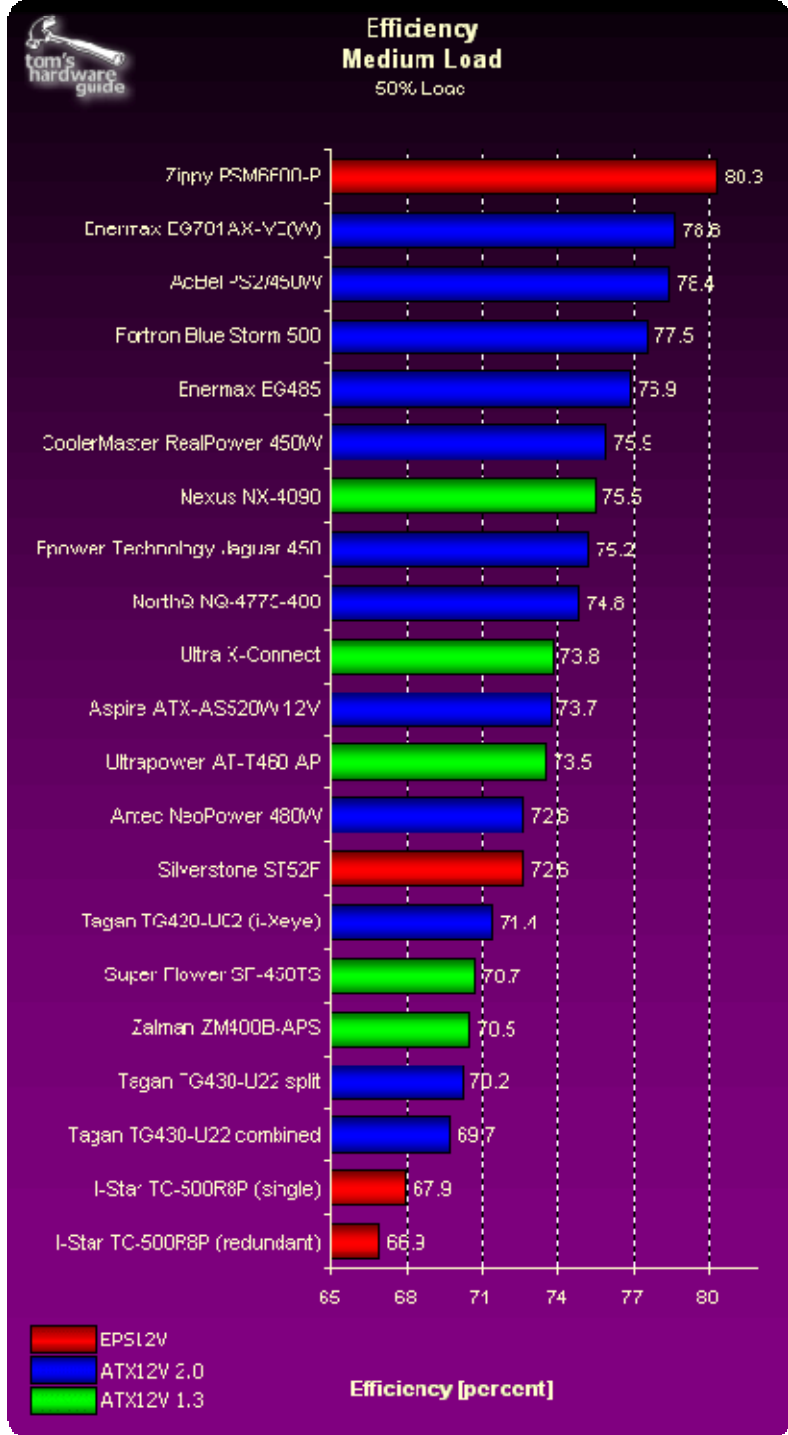






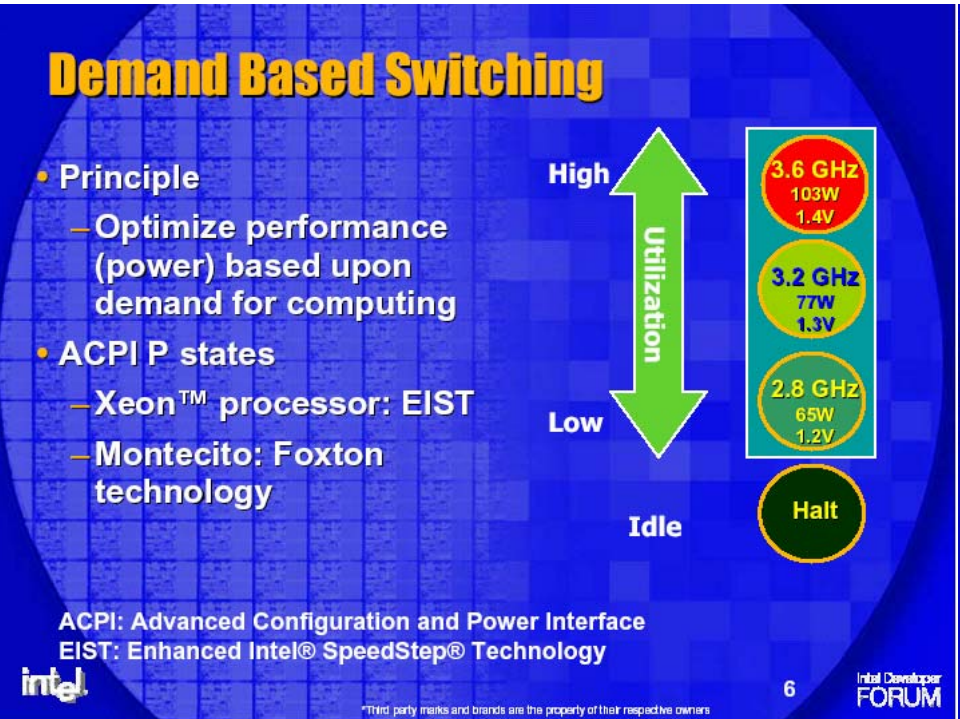
Excerpts from 2005 Tom's Hardware review of various desktop power supplies for efficiency and performance

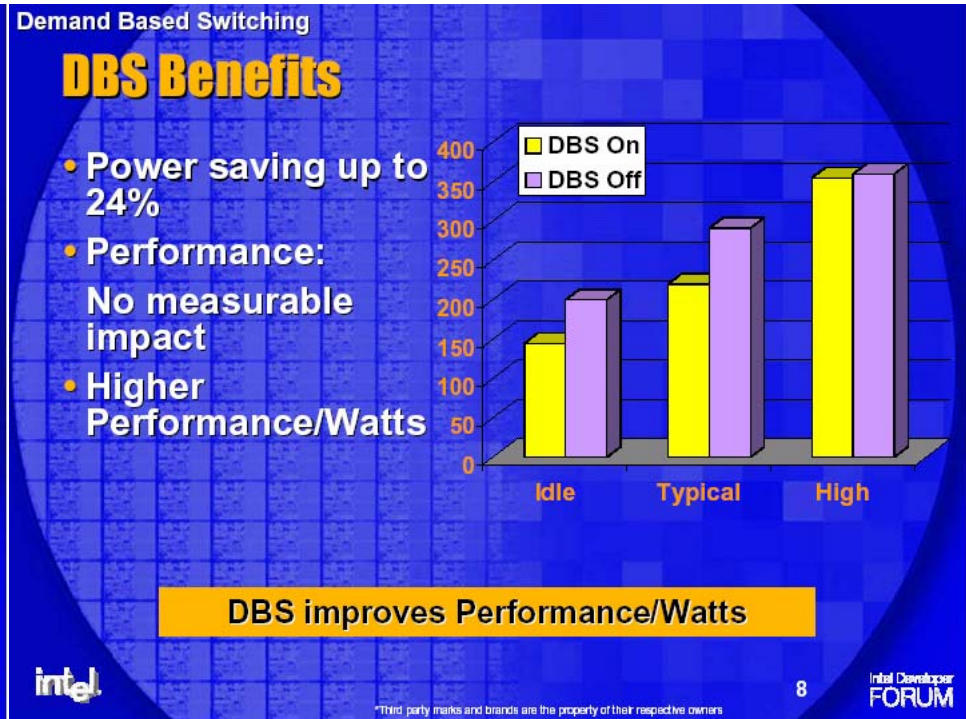




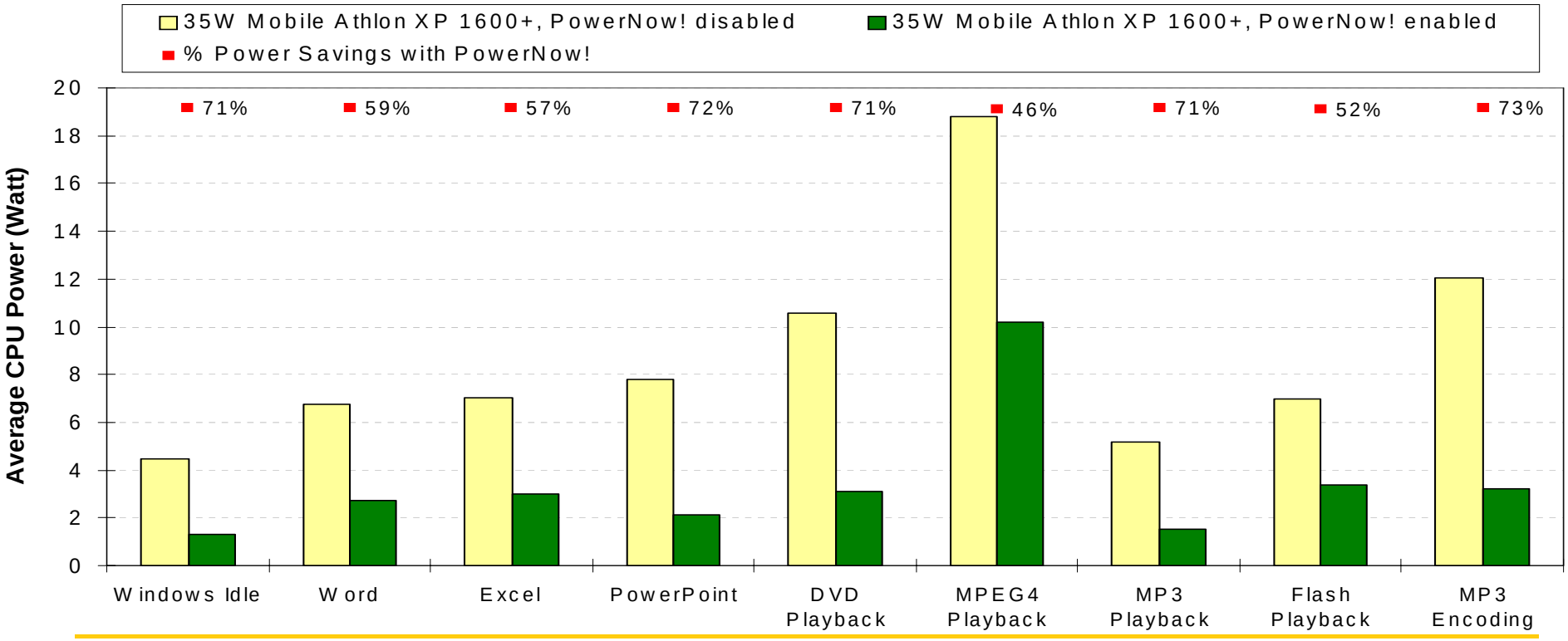
Processor Throttling: Comparable Performance, Reduced Energy Use

- More than one CPU manufacturer has created processors that scale CPU power requirements to load
- Processor throttling can cut processor power use by roughly 25 to 70% during periods of inactivity (idle)
- Processor throttling can cut system power use by roughly 12 to 24%, depending on system configuration and duty cycle



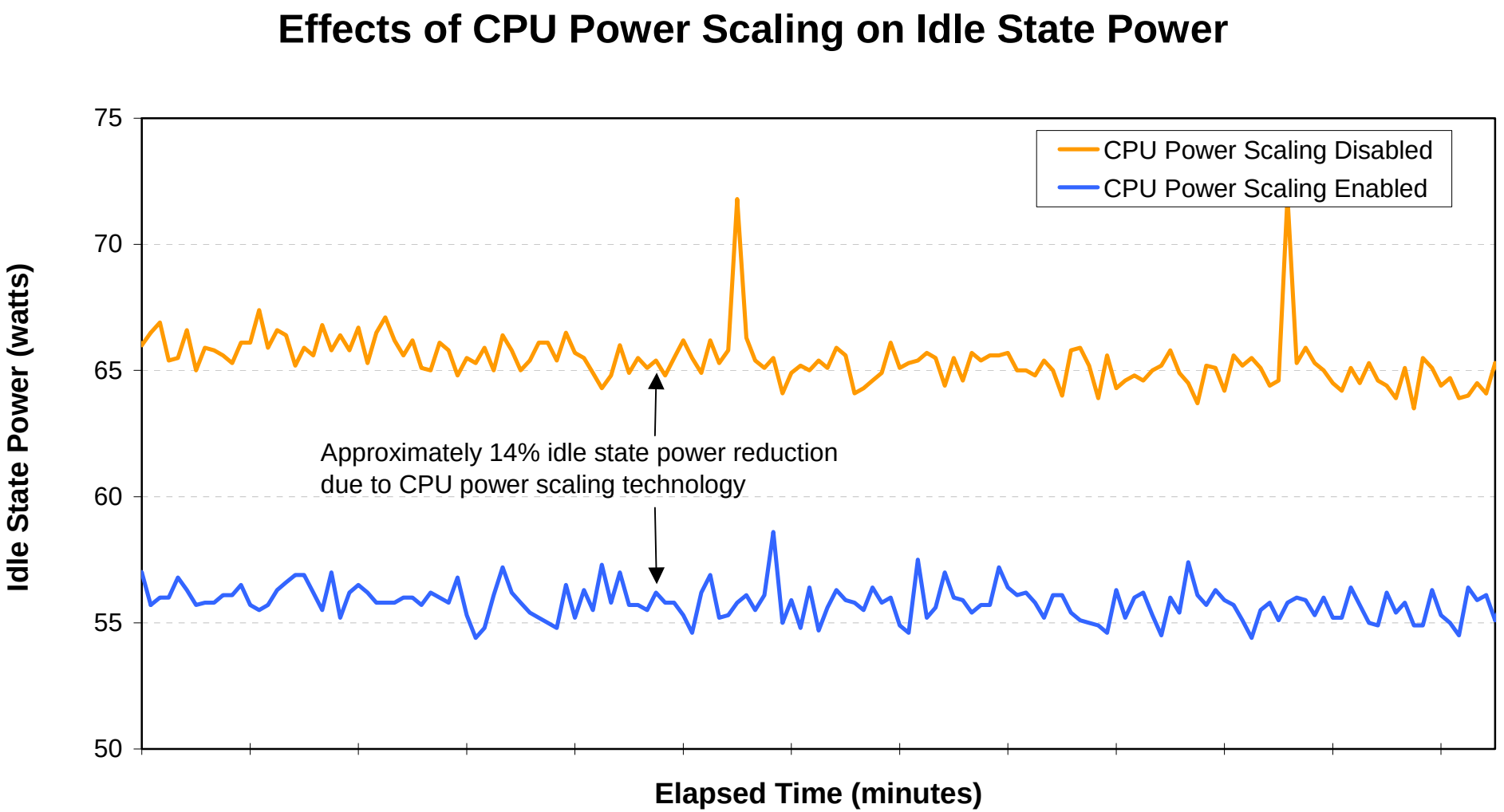


Another Example of Processor Throttling



Processor throttling also from Sun, Apple and Transmeta

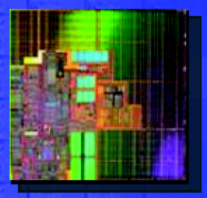
Ecos Lab Measurements of Processor Throttling in Idle State

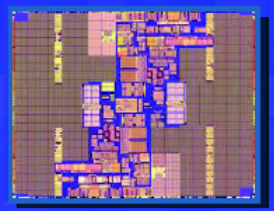


Big Energy Savings Potential Using Latest Generation Mobile Processors in Desktop Applications

The power challenge

Silicon Scaling Continues to Improve Density, Performance, Power, Cost
Server CPUs





	130 nm Madison	90 nm Montecito	
Cores/Threads	1/1	2/4	
Transistors	0.41	1.72	Billion
L3 Cache	6	24	MByte
Frequency	1.5	>1.7	GHz
Relative Performance	1	>1.5x	
Thermal Design Power	130	~100	Watt

Source: Intel

Silicon Scaling Continues to Improve Density, Performance, Power, Cost
Mobile CPUs

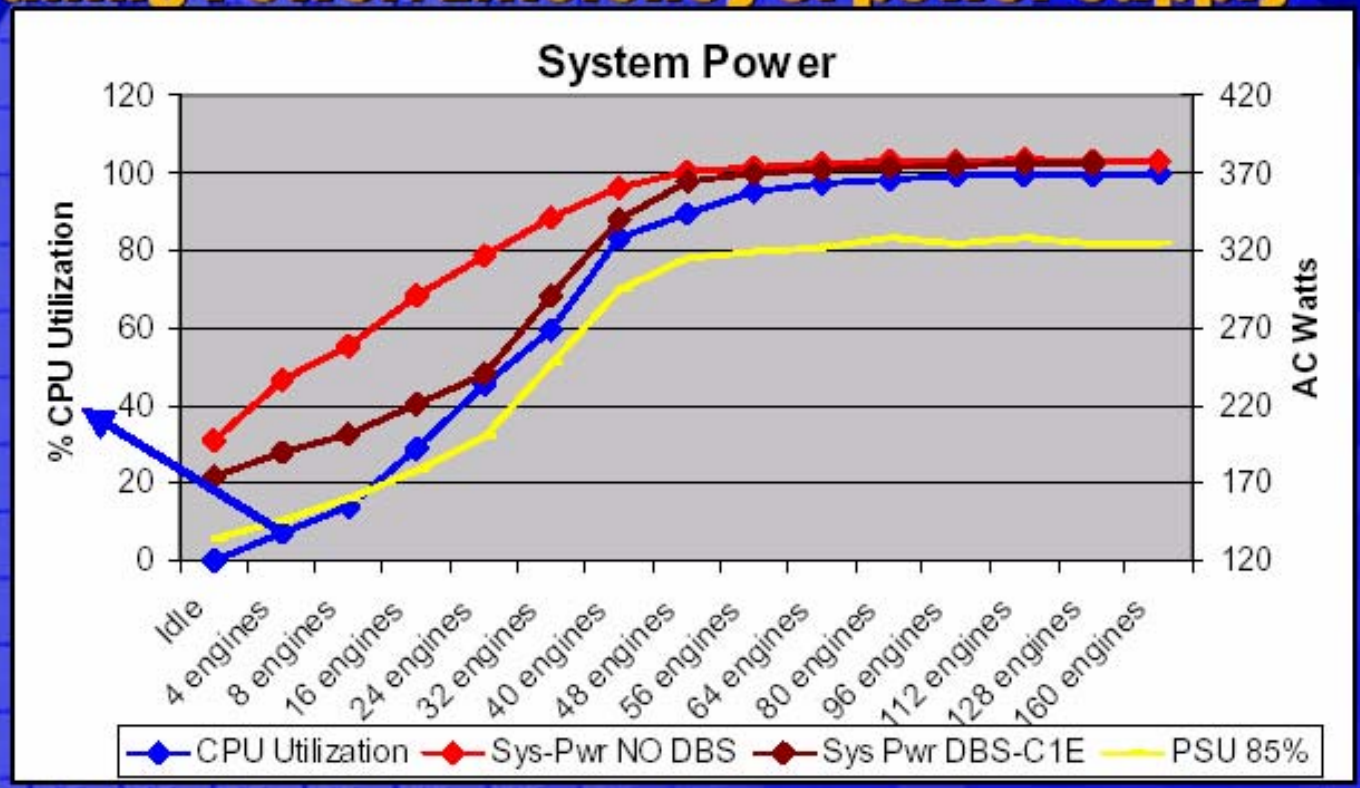
Pentium® M processor

	130 nm (Banias)	90 nm (Dothan)
Frequency	1.7 GHz	2.1 GHz
Transistors	77 million	140 million
Die size	83 mm²	87 mm²
L2 cache	1 MB	2 MB
Thermal design power	24.5 W	21 W

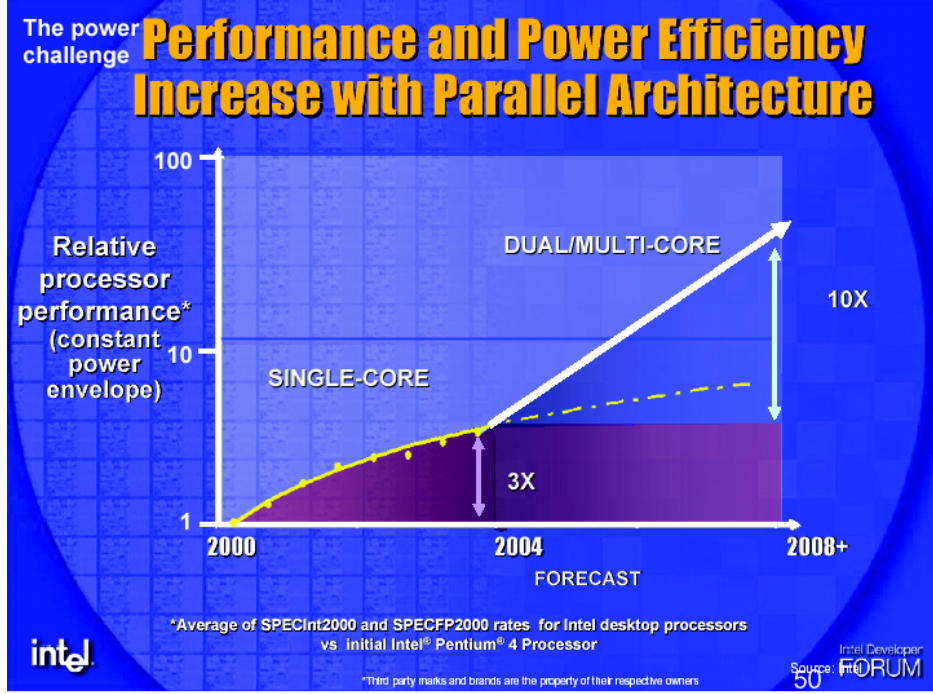
Source: Intel

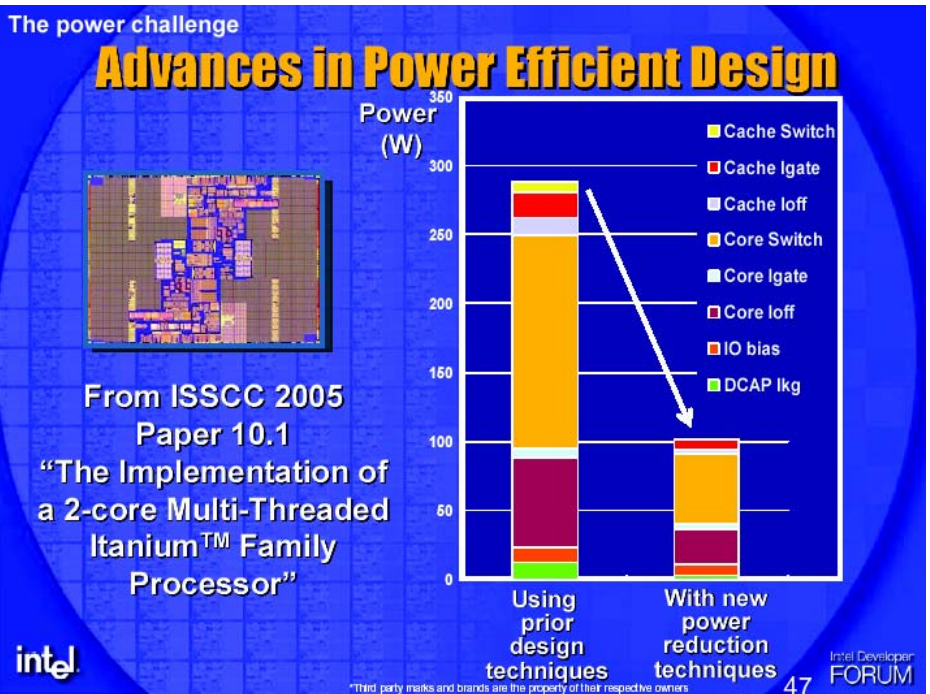
Efficient Power Supply Combined with Processor Throttling in Server

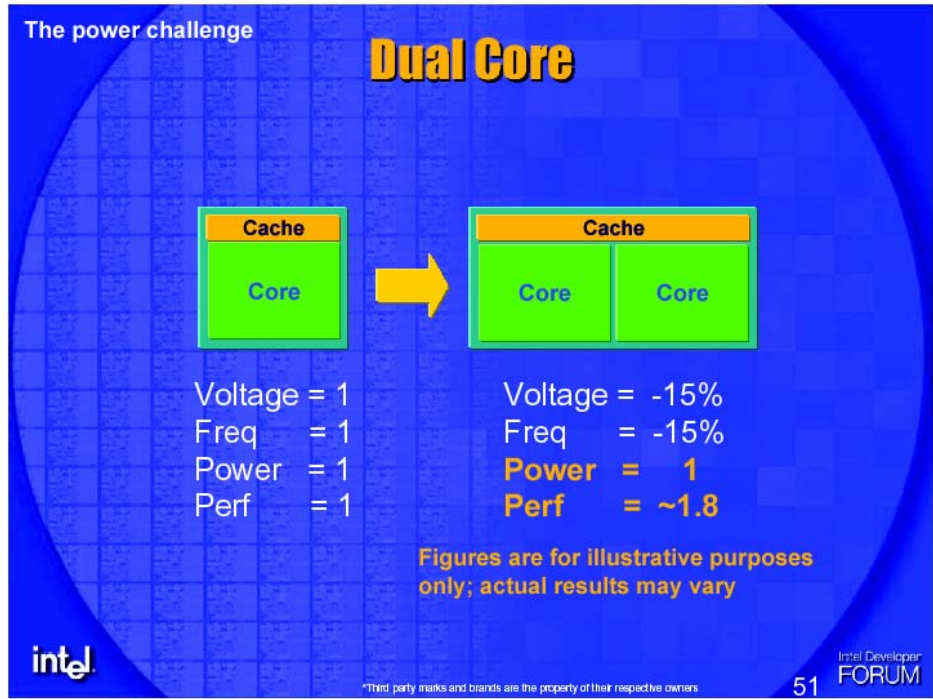
Tuning Power: Efficiency of power supply



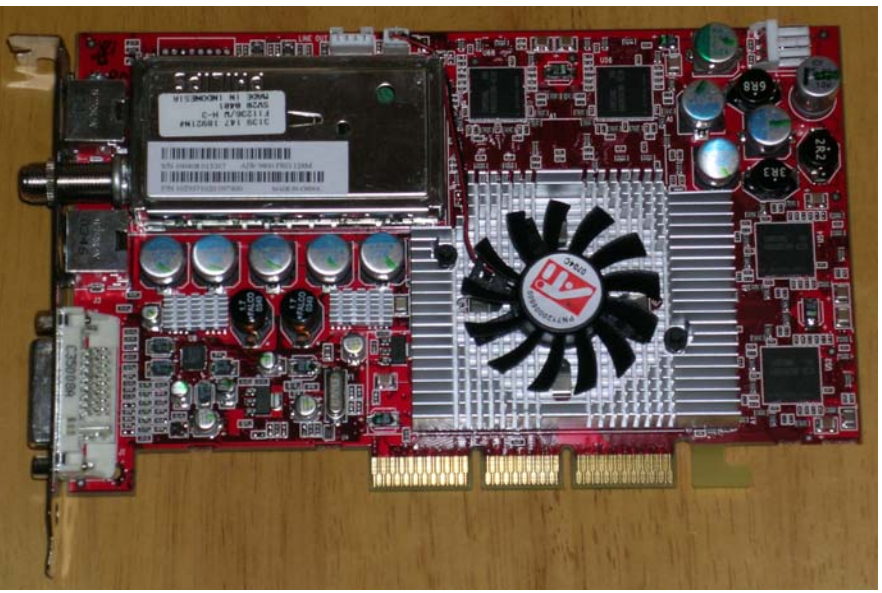
Other Indications of Potential for Reducing Processor Power

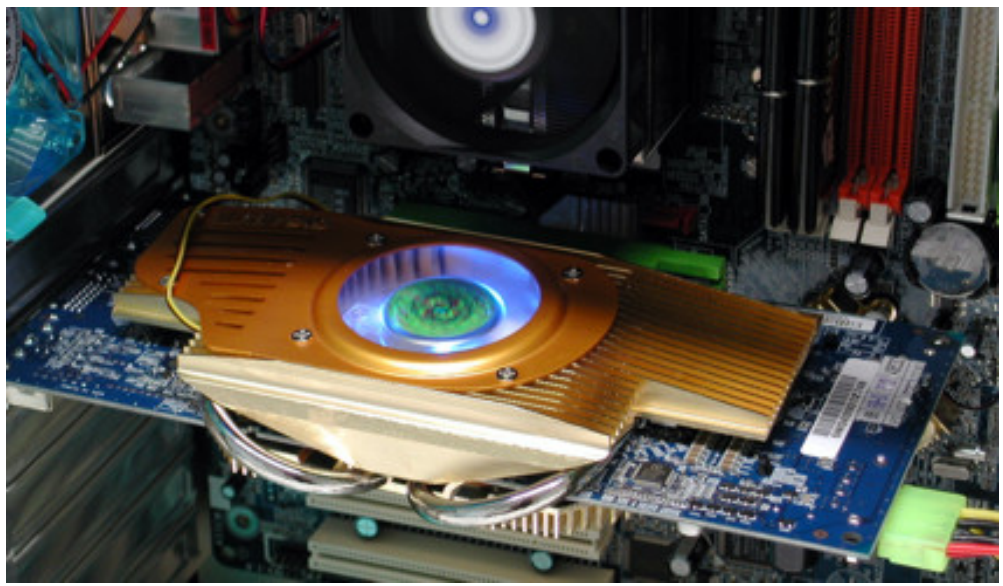




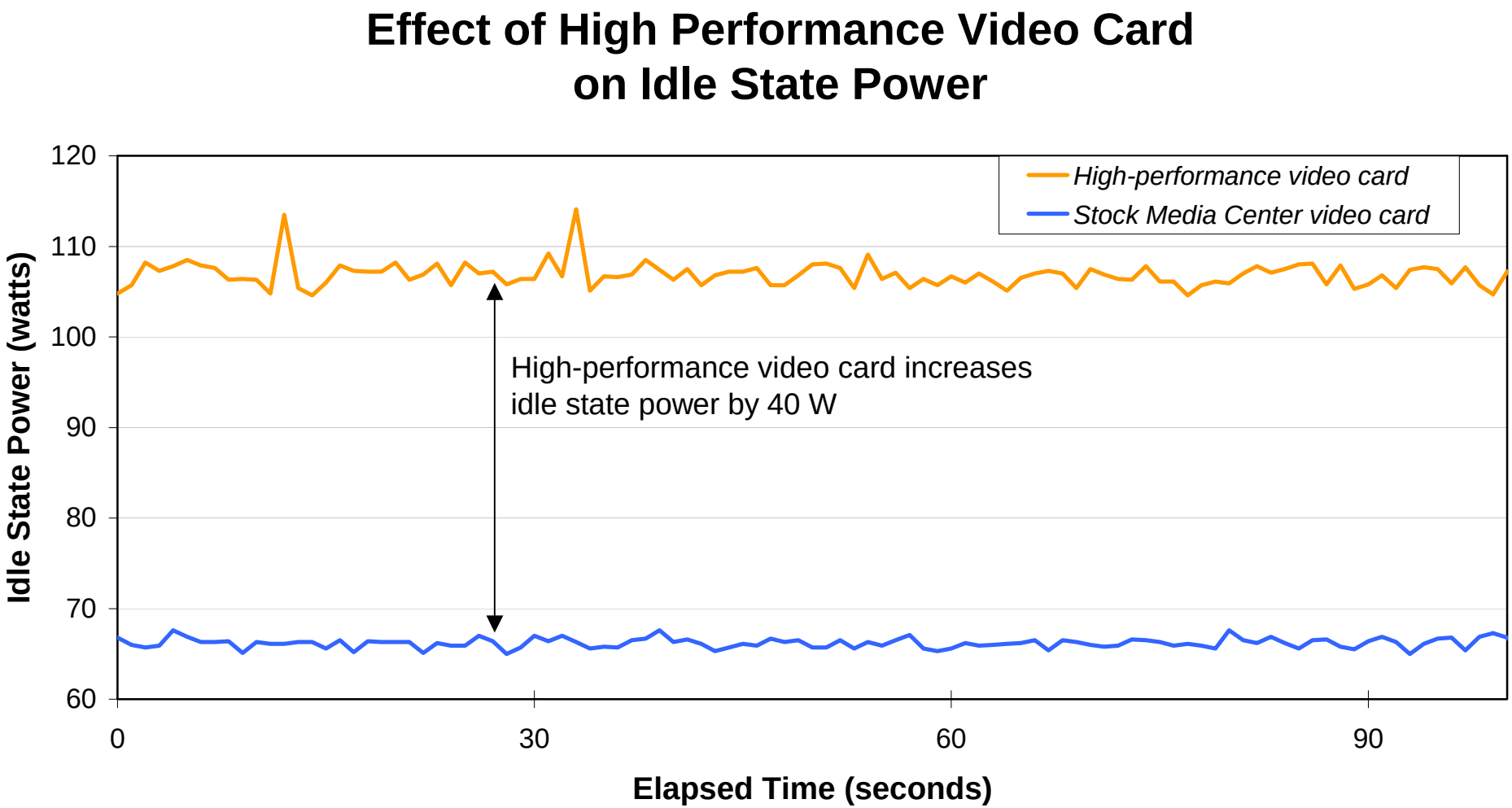


Video Card Companies Looking to Distinguish Themselves from Competition





Energy Use of Video Cards is Increasing



10 Fans in a Desktop PC?

1 side case fan

2 power supply fans

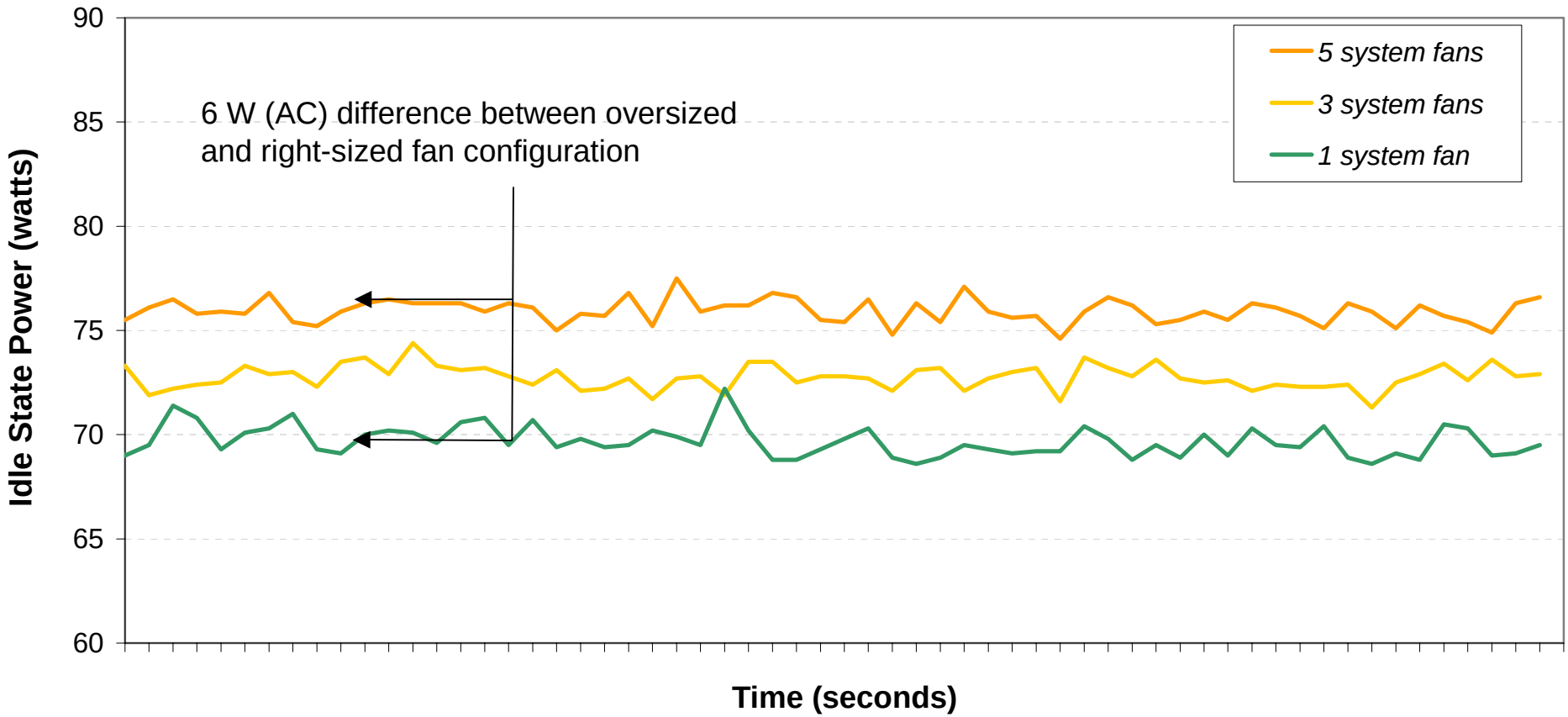
1 video card fan

2 motherboard fans

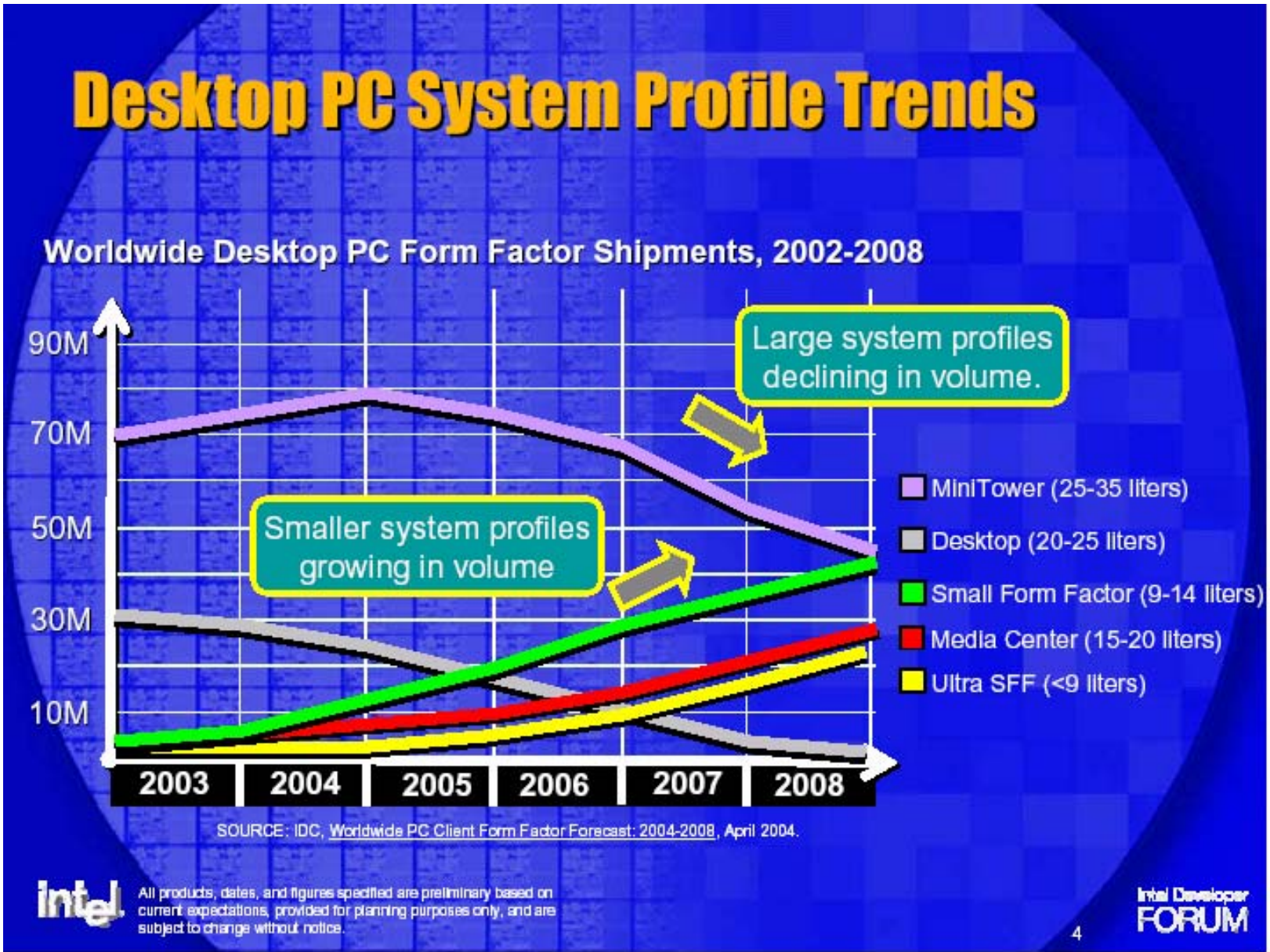
2 rear case fans

2 front case fans

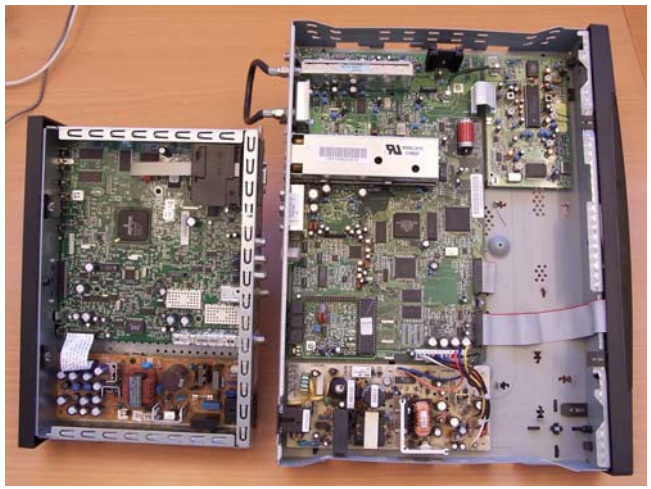
Ecos Measurements: Effects of Fan Configuration on Ac Power in Idle

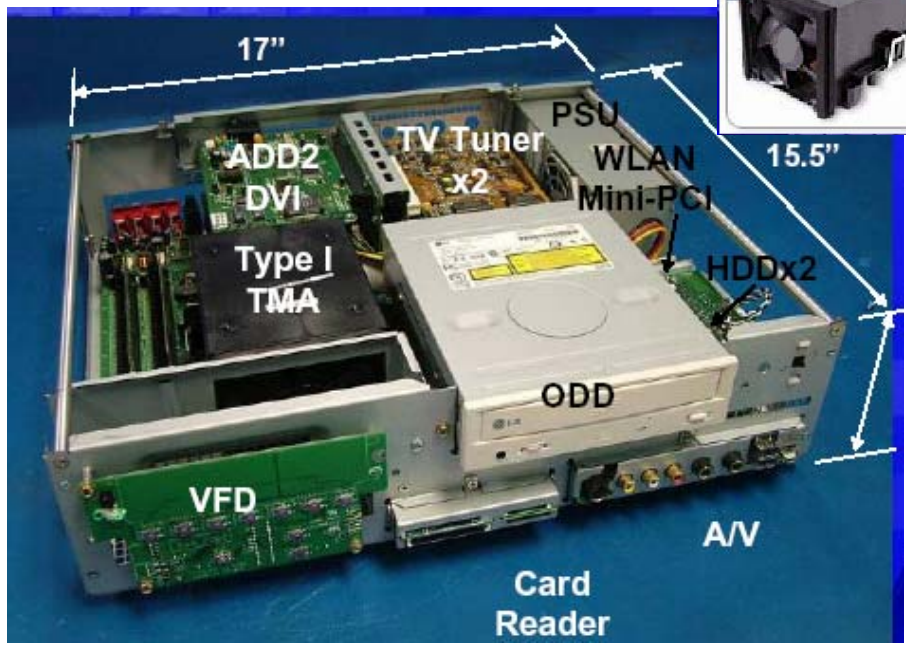


Quickly Growing is Market Share of Small Form Factors with the Most Efficient Thermal Solutions



Set Top Boxes, PCs & Home Audio/Video are Converging



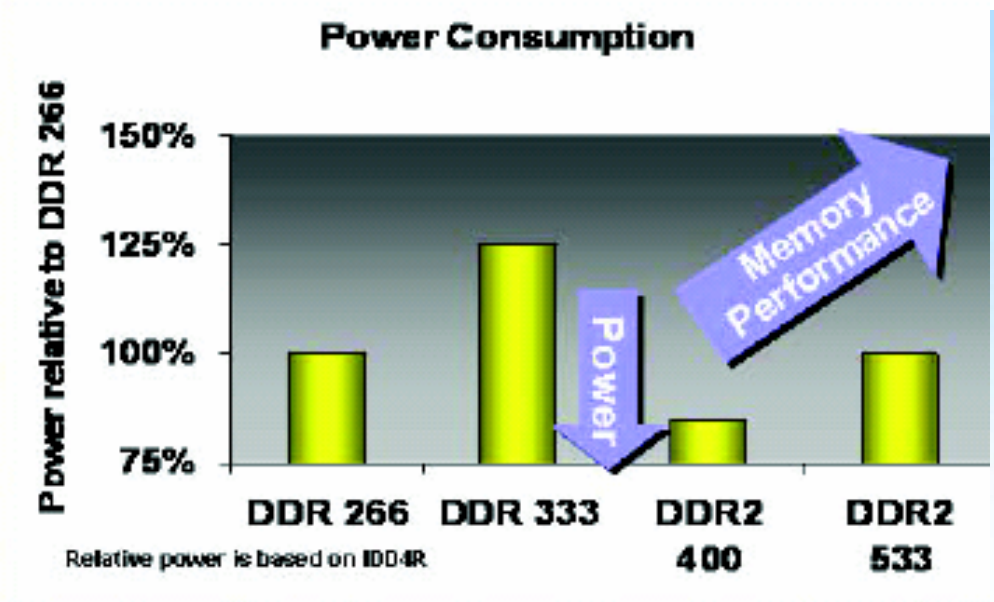


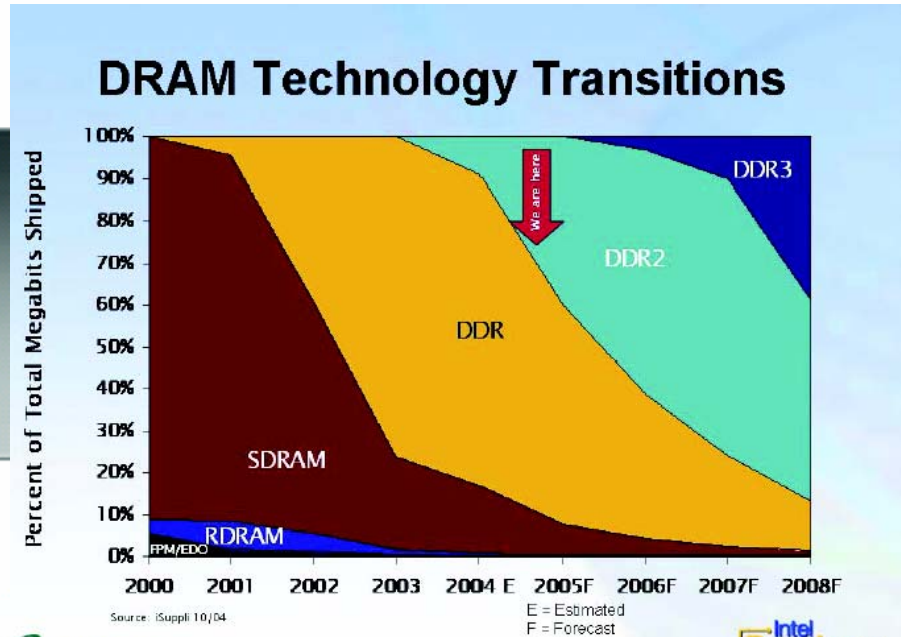
Advantages of Holistic System Design

- Cleaner, simpler installation of components
- Minimal need for long runs of loose cabling
- Better control of thermal performance in individual zones
- Allows more optimal sizing of power supply

Opportunities to Cut Memory Energy Use

- DDR2 is in the process of supplanting DDR memory – savings of about 20 to 25% by moving to a faster, lower voltage technology
- Infineon claims even lower energy use for its DDR2 modules than its competitors



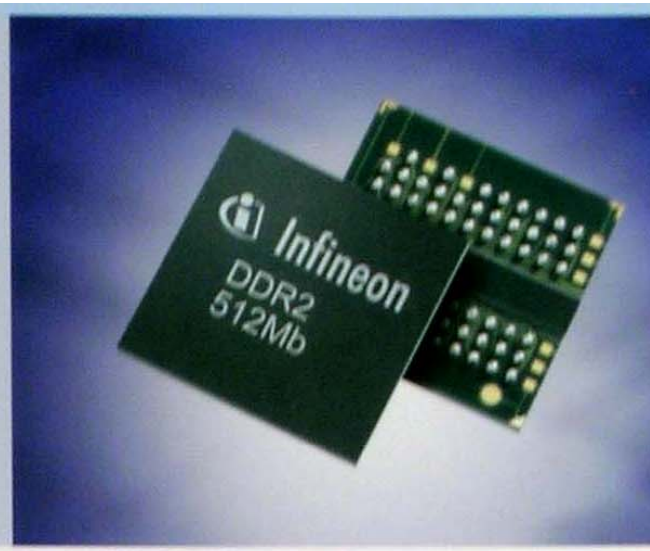


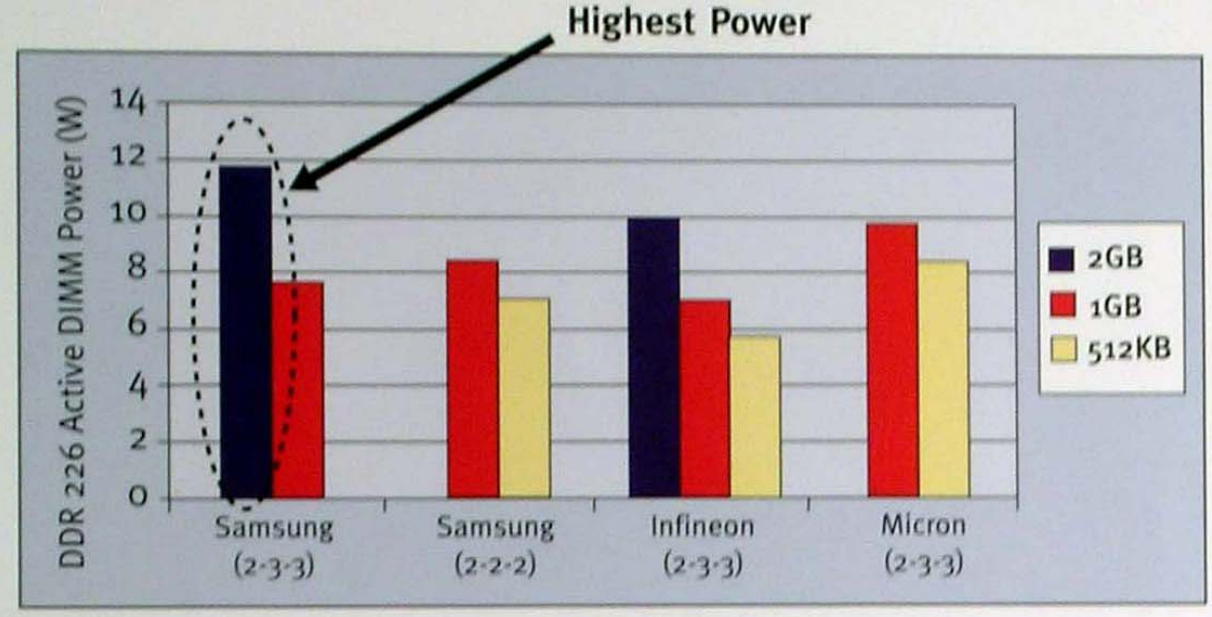
Micron

Intel Developer Forum

Infineon's Commodity DRAM

Lowest Power Consumption in the Industry

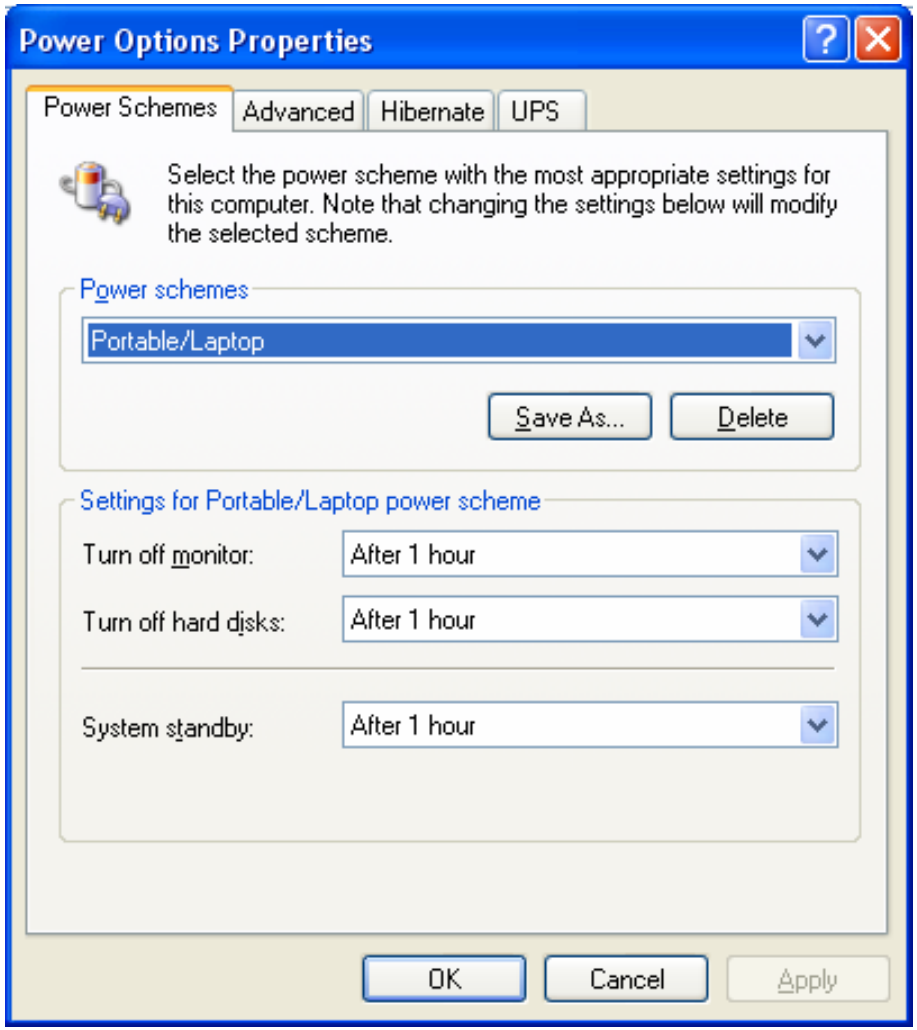


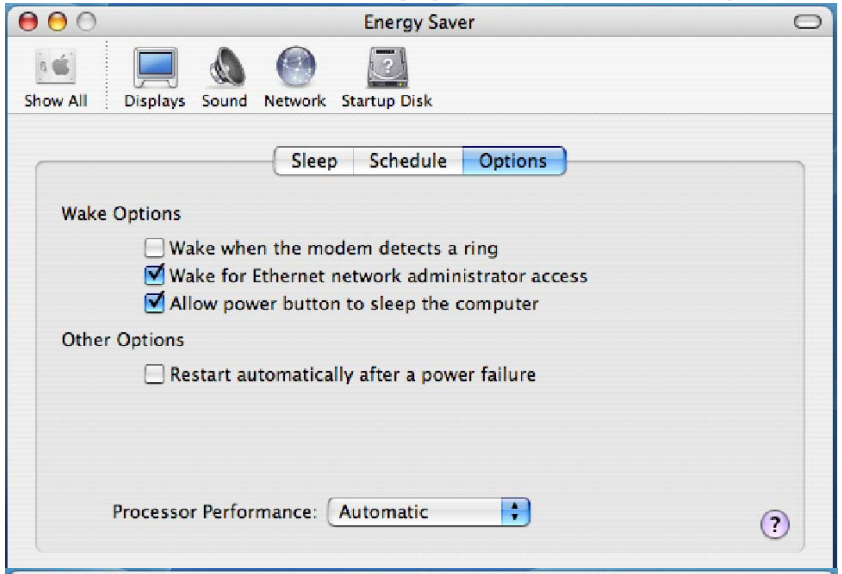


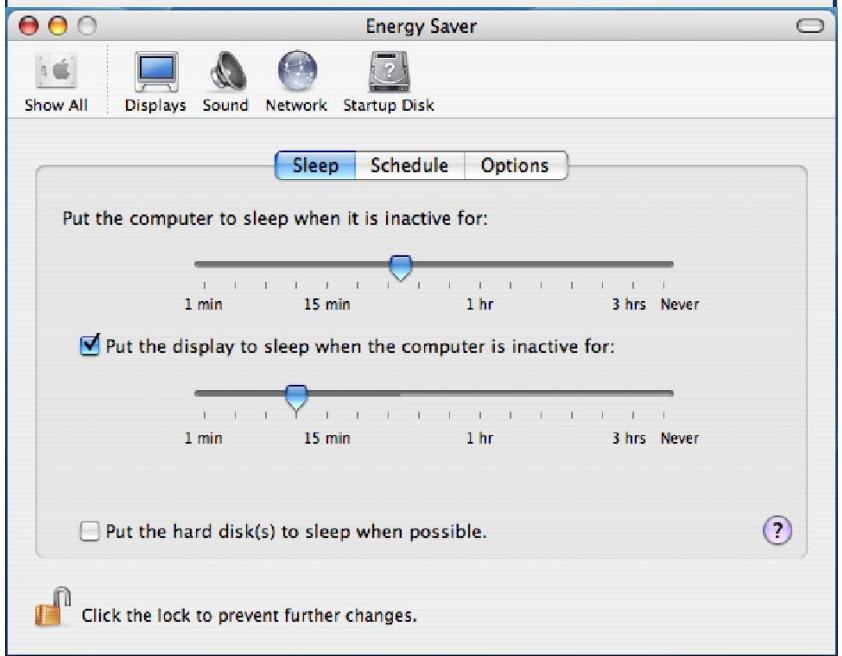
DDR1 – 30% LOWER Power

Brian Griffith, Presentation, Feb. 2004 IDF, "System Power Requirements: measurements and optimizing your power budgeting"

User Intuitive Software that Enables Hardware Solutions Important to Ensure Energy Savings



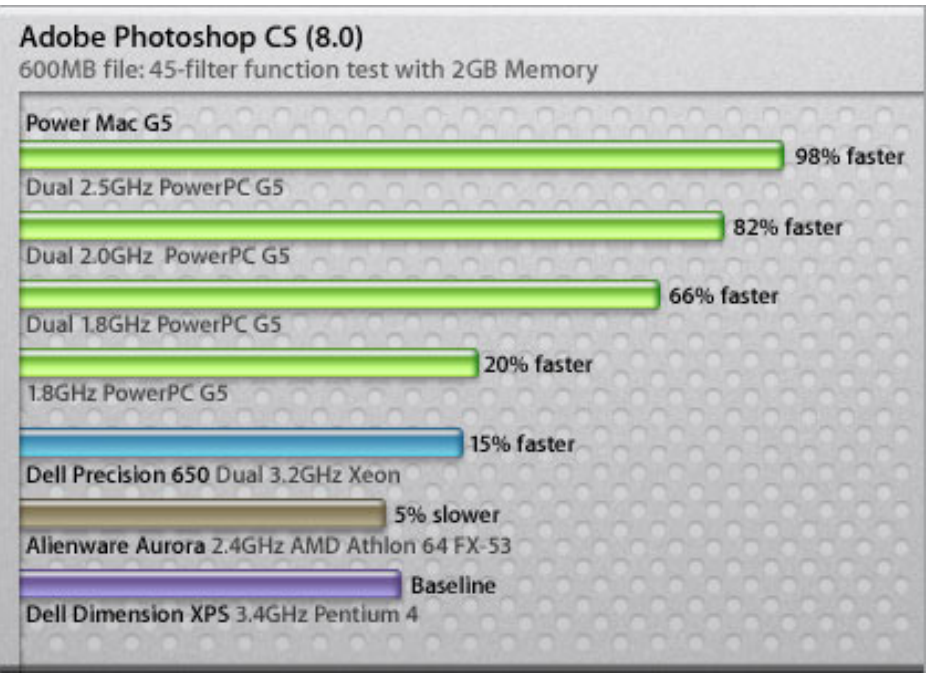


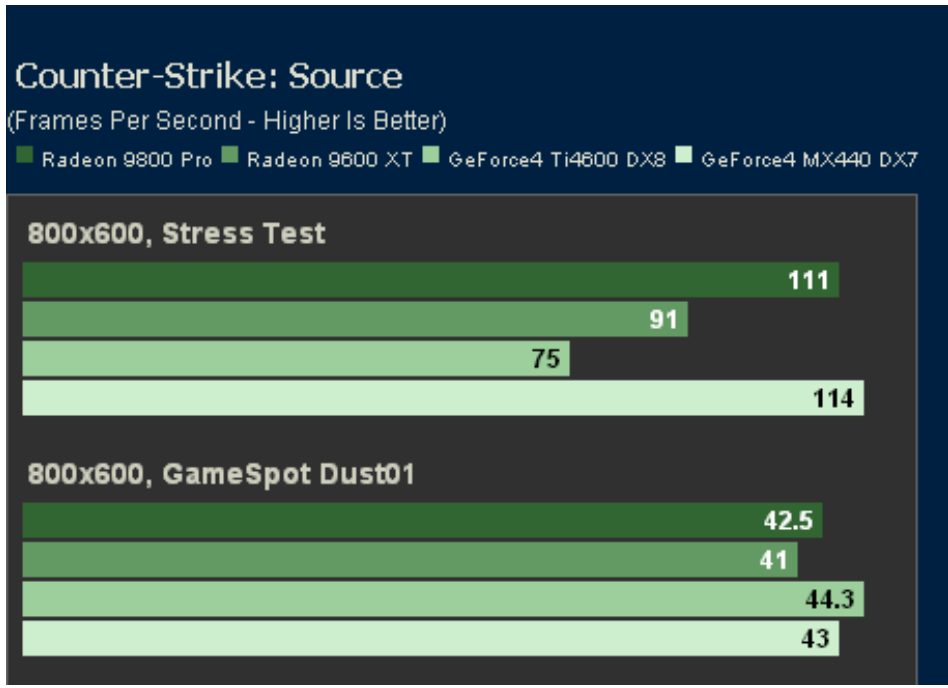


System Efficiency Approach

- Treat computer system as a black box and measure the system efficiency
- Use a software benchmark to simultaneously measure the energy use of computer and the performance over a set of established tasks
- Tasks performed by the computer over the course of the benchmark should be based on the way a computer is actually used in home and office environments
- One metric created for the efficiency of the computer; options include: Performance score per annual kWh, performance score per Wh
- Measure the efficiency of the interaction of all the components inside the housing of the computer and leave the power engineering to the OEMs and component manufacturers

Benchmarking Already Routinely Used in Computer Industry Marketing Campaigns and Buyers' Guides





Energy Efficiency Benchmark

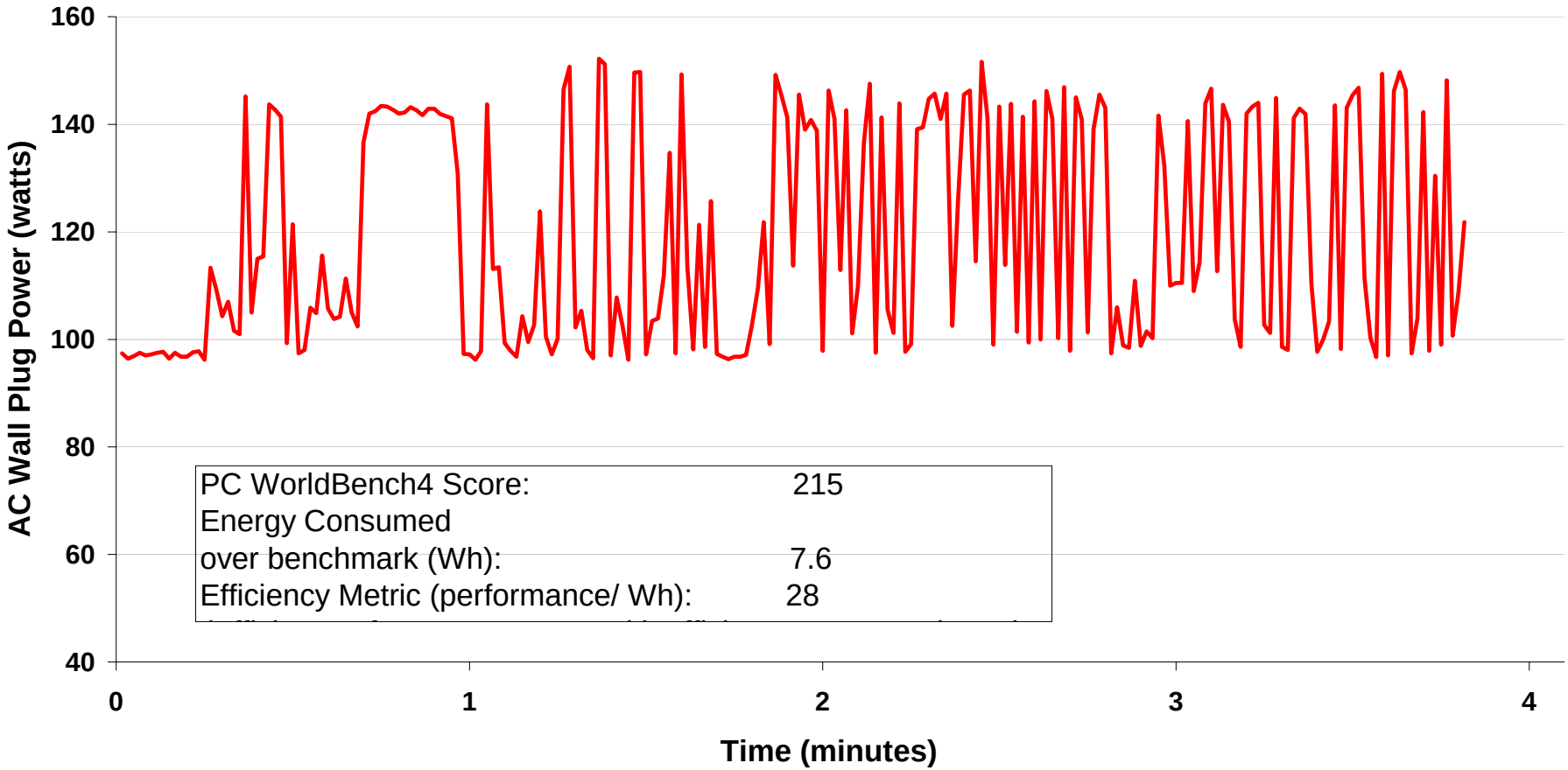
- Ideal benchmark
  - Characterize the typical duty cycle of computer in home/office/data center
  - Developed independent of one specific hardware technology or software platform (enable fair comparison of Apple/Linux/Unix/ Windows machines and Apple/AMD/Intel/Transmeta based machines)
  - Relatively easy to use for quick turn-around measurement in laboratory
- Benchmark that incorporates all of these characteristics does not exist in market today, elements are found scattered in different solutions
- Server software benchmark examples

Benchmark Name	***Representative of Typical Client Load***	***Representative of Maximum Client Load***
WebStone	X	
NetBench	X	
Webserver Stress Tool	X	X

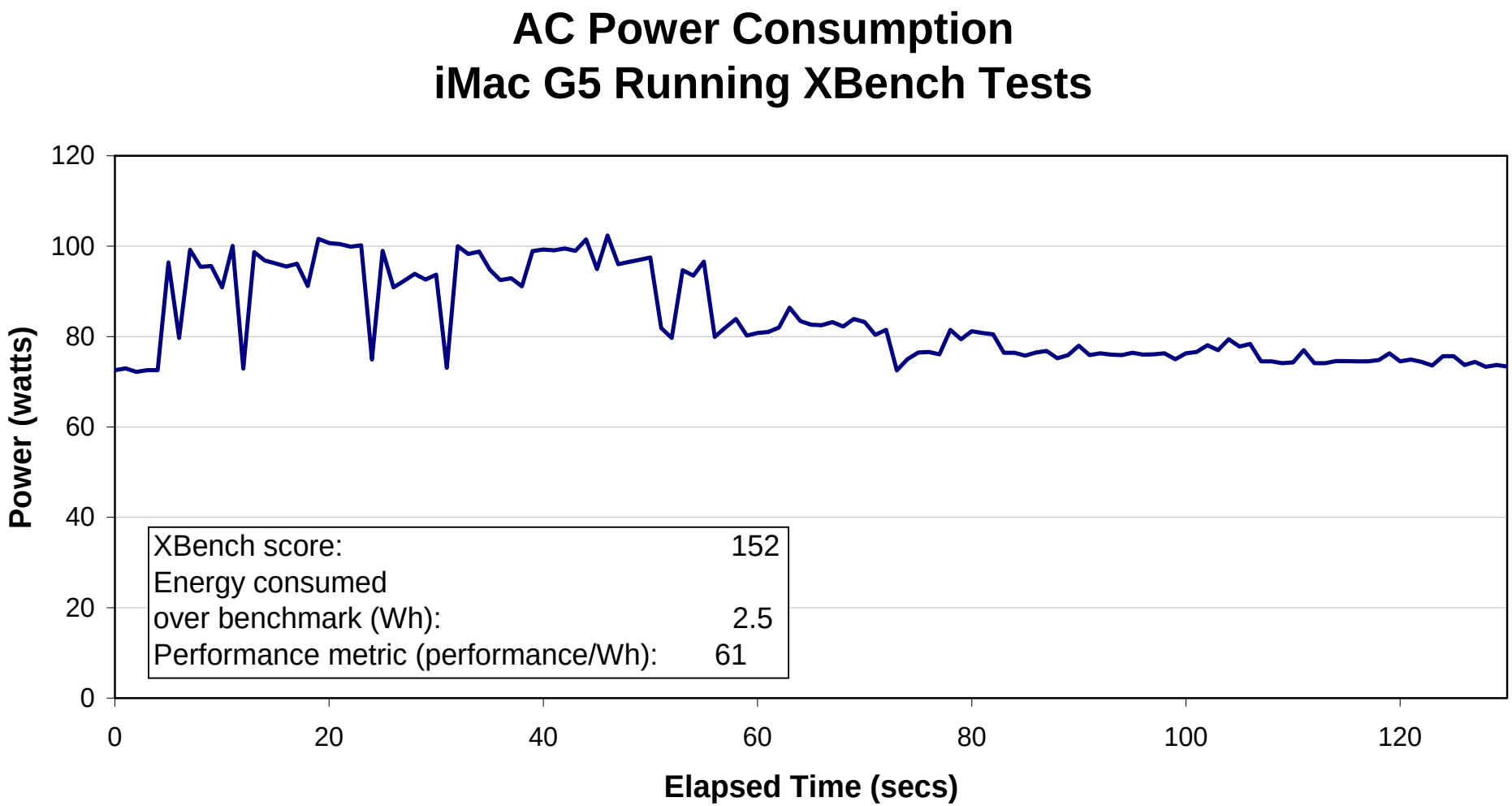
Examples of Desktop Benchmark Software

Benchmark Name	***Representative of Normal Processing***	***Representative of Maximum Processing***
PC WorldBench	**X**	
PCMark		**X**
SysMark	**X**	
Performance Test		**X**
Fresh Diagnose		**X**
Business Winstone	**X**	
WinBench		**X**
SpeedMark (Apple)		**X**
SANDRA		**X**
Alterion Acceptable Level of Performance	**X**	
XBench (Apple)		**X**

Benchmark Concept: Windows Based Systems



Benchmark Concept: Apple Based Systems



System Configuration	*PCMark 2004 Score*	*Energy Consumed Over Benchmark (Wh)*	*Efficiency Metric (performance /Wh)*
AMD based with high efficiency (85%), right-sized PS (250W)	3595	17.1	211
AMD-based with high efficiency (79%), oversized PS (450W)	3574	20	178
AMD-based with stock configuration	3603	20.5	176
AMD-based with CPU power scaling technology enabled	3571	20.5	174
Intel-based with high efficiency (85%), appropriately-sized PS (250W)	3642	21.6	169
AMD-based with low efficiency (70%), oversized PS (480W)	3580	24.3	147
Intel-based with high efficiency (79%), oversized PS (450W)	3654	26.6	137
Intel-based with stock configuration	3583	28	128
AMD-based with high performance video card	3963	32	124
Intel-based with low efficiency (70%), oversized PS (480W)	3576	31.4	114
Intel-based with nigh performance video card	4043	38.7	104

Range of System Configurations

High-power

- 5 system fans
- High-end video card
- Power scaling disabled
- Oversized, inefficient power supply

Standard

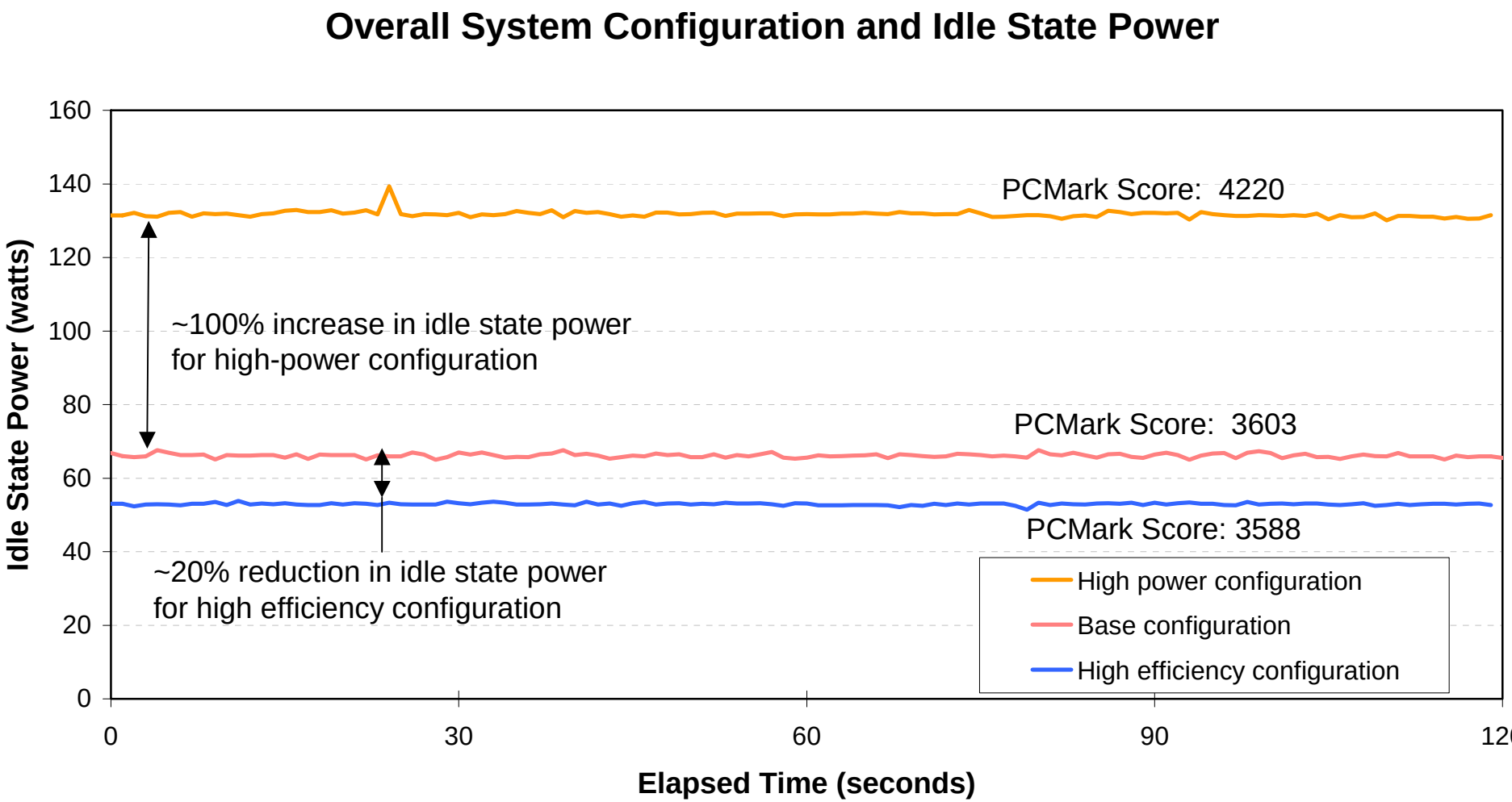
- 1 system fan
- Stock video card
- Power scaling disabled
- Right-sized, inefficient power supply

Efficient

- 1 system fan
- Stock video card
- Power scaling CPU enabled
- Right-sized, efficient power supply

AMD Athlon 64 2800+ based desktop system

Energy Use and Benchmark Score of 3 Desktop PC Configurations



How Many Software Benchmarks?

- Single benchmark that measures desktops, laptops, workstations, and servers
- Different benchmarks for different applications
  - One for desktops and laptops, one for servers and workstations
- One benchmarks enables comparisons across different form factors
- Multiple benchmarks enables tests to more closely match actual user behavior

Component Approach	System Approach
Easier to research and specify in the near term	Requires more research time in the near term
Because it is technology specific, could become obsolete as the industry rapidly changes	More robust approach that can adapt as new technologies are adopted
More difficult to update on a regular basis than performance approach; requires detailed knowledge of component changes over time	Easier to update the specification in future, measurement methodology can change infrequently
Requires specific solutions known to reduce energy consumption	Remains open to new solutions and innovations to save energy that are not currently available

Timeline for Tier 2

- Further research to be conducted in 2005
  - Measuring and evaluating components
  - Evaluating benchmarks and working with benchmarking companies to get feedback on energy efficiency benchmark
- Update at next stakeholder workshop