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
Peak Power of Desktop Computers Rising

Projected Change in Peak Power Consumption of Desktop Computers

- Power Supply
- Other
- VRMs
- Graphics Card
- CPU

<table>
<thead>
<tr>
<th>Year</th>
<th>Power Supply</th>
<th>Other</th>
<th>VRMs</th>
<th>Graphics Card</th>
<th>CPU</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>43%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>30%</td>
<td>57%</td>
</tr>
<tr>
<td>2004</td>
<td>30%</td>
<td>23%</td>
<td>10%</td>
<td>20%</td>
<td>37%</td>
<td>70%</td>
</tr>
<tr>
<td>2005</td>
<td>20%</td>
<td>41%</td>
<td>10%</td>
<td>20%</td>
<td>39%</td>
<td>80%</td>
</tr>
</tbody>
</table>

80% typical power supply efficiency
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

- **Light Load Conditions**
  - Min: 77 W, 14%
  - Idle: 161 W, 30%
  - Operating: 247 W, 45%

- **Power Supply Efficiency**
  - Power supply efficiency drops 10% at minimum load condition

- **Effect of PSU Efficiency & Sizing on Idle State Power, Intel-based system**
  - Average Efficiency:
    - 65%: 50.1 W
    - 70%: 59.3 W
    - 75%: 62.6 W
    - 80%: 80.7 W

- **Nameplate DC Power Rating (watts)**
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

**Demand Based Switching**
- Principle
  - Optimize performance (power) based upon demand for computing
- ACPI P states
  - Xeon™ processor: EIST
  - Montecito: Foxton technology

**DBS Benefits**
- Power saving up to 24%
- Performance: No measurable impact
- Higher Performance/Watts

DBS improves Performance/Watts

ACPI: Advanced Configuration and Power Interface
EIST: Enhanced Intel® SpeedStep® Technology
Another Example of Processor Throttling

Processor throttling also from Sun, Apple and Transmeta
Ecos Lab Measurements of Processor Throttling in Idle State

Effects of CPU Power Scaling on Idle State Power

Approximately 14% idle state power reduction due to CPU power scaling technology
Big Energy Savings Potential Using Latest Generation Mobile Processors in Desktop Applications
Efficient Power Supply Combined with Processor Throttling in Server
Other Indications of Potential for Reducing Processor Power
Video Card Companies Looking to Distinguish Themselves from Competition
Energy Use of Video Cards is Increasing

Effect of High Performance Video Card on Idle State Power

High-performance video card increases idle state power by 40 W
10 Fans in a Desktop PC?

1 side case fan
2 motherboard fans
2 power supply fans
2 rear case fans
1 video card fan
2 front case fans
Ecos Measurements: Effects of Fan Configuration on Ac Power in Idle

6 W (AC) difference between oversized and right-sized fan configuration
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
Infineon’s Commodity DRAM
Lowest Power Consumption in the Industry

Highest Power

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

**Adobe Photoshop CS (8.0)**

- **Power Mac G5**: 98% faster
- **Dual 2.5GHz PowerPC G5**: 82% faster
- **Dual 2.0GHz PowerPC G5**: 66% faster
- **Dual 1.8GHz PowerPC G5**: 20% faster
- **1.8GHz PowerPC G5**: 15% faster
- **Dell Precision 650 Dual 3.2GHz Xeon**: 5% slower
- **Alienware Aurora 2.4GHz AMD Athlon 64 FX-53**: Baseline
- **Dell Dimension XPS 3.4GHz Pentium 4**: Baseline

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**Counter-Strike: Source**

(Frames Per Second - Higher Is Better)

- Radeon 9800 Pro
- Radeon 9800 XT
- GeForce4 Ti4600 DX8
- GeForce4 MX440 DX7

**800x600, Stress Test**

- **111**
- **91**
- **75**
- **114**

**800x600, GameSpot Dust01**

- **42.5**
- **41**
- **44.3**
- **43**
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

<table>
<thead>
<tr>
<th>Benchmark Name</th>
<th>Representative of Typical Client Load</th>
<th>Representative of Maximum Client Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>WebStone</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>NetBench</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Webserver Stress Tool</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
### Examples of Desktop Benchmark Software

<table>
<thead>
<tr>
<th>Benchmark Name</th>
<th>Representative of Normal Processing</th>
<th>Representative of Maximum Processing</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC WorldBench</td>
<td>X</td>
<td></td>
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<tr>
<td>PCMark</td>
<td></td>
<td>X</td>
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<tr>
<td>SysMark</td>
<td>X</td>
<td></td>
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<tr>
<td>Performance Test</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Fresh Diagnose</td>
<td></td>
<td>X</td>
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<tr>
<td>Business Winstone</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>WinBench</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>SpeedMark (Apple)</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>SANDRA</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Alterion Acceptable Level of Performance</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>XBench (Apple)</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
Benchmark Concept: Windows Based Systems

PC WorldBench4 Score: 215
Energy Consumed over benchmark (Wh): 7.6
Efficiency Metric (performance/ Wh): 28
Benchmark Concept: Apple Based Systems

AC Power Consumption
iMac G5 Running XBench Tests

XBech score: 152
Energy consumed over benchmark (Wh): 2.5
Performance metric (performance/Wh): 61
<table>
<thead>
<tr>
<th>System Configuration</th>
<th>PCMark 2004 Score</th>
<th>Energy Consumed Over Benchmark (Wh)</th>
<th>Efficiency Metric (performance /Wh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMD based with high efficiency (85%), right-sized PS (250W)</td>
<td>3595</td>
<td>17.1</td>
<td>211</td>
</tr>
<tr>
<td>AMD-based with high efficiency (79%), oversized PS (450W)</td>
<td>3574</td>
<td>20</td>
<td>178</td>
</tr>
<tr>
<td>AMD-based with stock configuration</td>
<td>3603</td>
<td>20.5</td>
<td>176</td>
</tr>
<tr>
<td>AMD-based with CPU power scaling technology enabled</td>
<td>3571</td>
<td>20.5</td>
<td>174</td>
</tr>
<tr>
<td>Intel-based with high efficiency (85%), appropriately-sized PS (250W)</td>
<td>3642</td>
<td>21.6</td>
<td>169</td>
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<tr>
<td>AMD-based with low efficiency (70%), oversized PS (480W)</td>
<td>3580</td>
<td>24.3</td>
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<tr>
<td>Intel-based with high efficiency (79%), oversized PS (450W)</td>
<td>3654</td>
<td>26.6</td>
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<tr>
<td>Intel-based with stock configuration</td>
<td>3583</td>
<td>28</td>
<td>128</td>
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<tr>
<td>AMD-based with high performance video card</td>
<td>3963</td>
<td>32</td>
<td>124</td>
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<tr>
<td>Intel-based with low efficiency (70%), oversized PS (480W)</td>
<td>3576</td>
<td>31.4</td>
<td>114</td>
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<tr>
<td>Intel-based with high performance video card</td>
<td>4043</td>
<td>38.7</td>
<td>104</td>
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<tr>
<td>Range of System Configurations</td>
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<td>-----------------------------------------------</td>
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<tr>
<td><strong>High-power</strong></td>
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<tr>
<td>- 5 system fans</td>
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<tr>
<td>- High-end video card</td>
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<tr>
<td>- Power scaling disabled</td>
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<tr>
<td>- Oversized, inefficient power supply</td>
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<tr>
<td><strong>Standard</strong></td>
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<tr>
<td>- 1 system fan</td>
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<td></td>
<td></td>
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<tr>
<td>- Stock video card</td>
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<td></td>
<td></td>
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<tr>
<td>- Power scaling disabled</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>- Right-sized, inefficient power supply</td>
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<tr>
<td><strong>Efficient</strong></td>
<td></td>
<td></td>
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<tr>
<td>- 1 system fan</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>- Stock video card</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>- Power scaling CPU enabled</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Right-sized, efficient power supply</td>
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</tbody>
</table>

AMD Athlon 64 2800+ based desktop system
Energy Use and Benchmark Score of 3 Desktop PC Configurations

Overall System Configuration and Idle State Power

~100% increase in idle state power for high-power configuration

~20% reduction in idle state power for high efficiency configuration

PCMark Score: 4220
PCMark Score: 3603
PCMark Score: 3588

Elapsed Time (seconds)

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