Battery Life Challenges on Future Mobile Platforms

Dr. Shreekant (Ticky) S. Thakkar
Director of Mobile Technology
Mobile Platforms Group
Intel Corporation

IEEE Symposium on Low Power Electronics and Design
August 10th, 2004

Disclaimer

Actual measurement results may vary depending on the specific hardware and software configuration of the computer system measured, the characteristics of those computer components not under direct measurement, variation in processor manufacturing processes, the benchmark utilized, the specific ambient conditions under which the measurement is taken, and other factors.

Agenda

- Mobility Is Happening
- Battery Life
- Energy Sources
- Energy Consumers
- Summary

Agenda

- **Mobility Is Happening**
- **Battery Life**
- **Energy Sources**
- **Energy Consumers**
- **Summary**

Intel's Mobility Vision

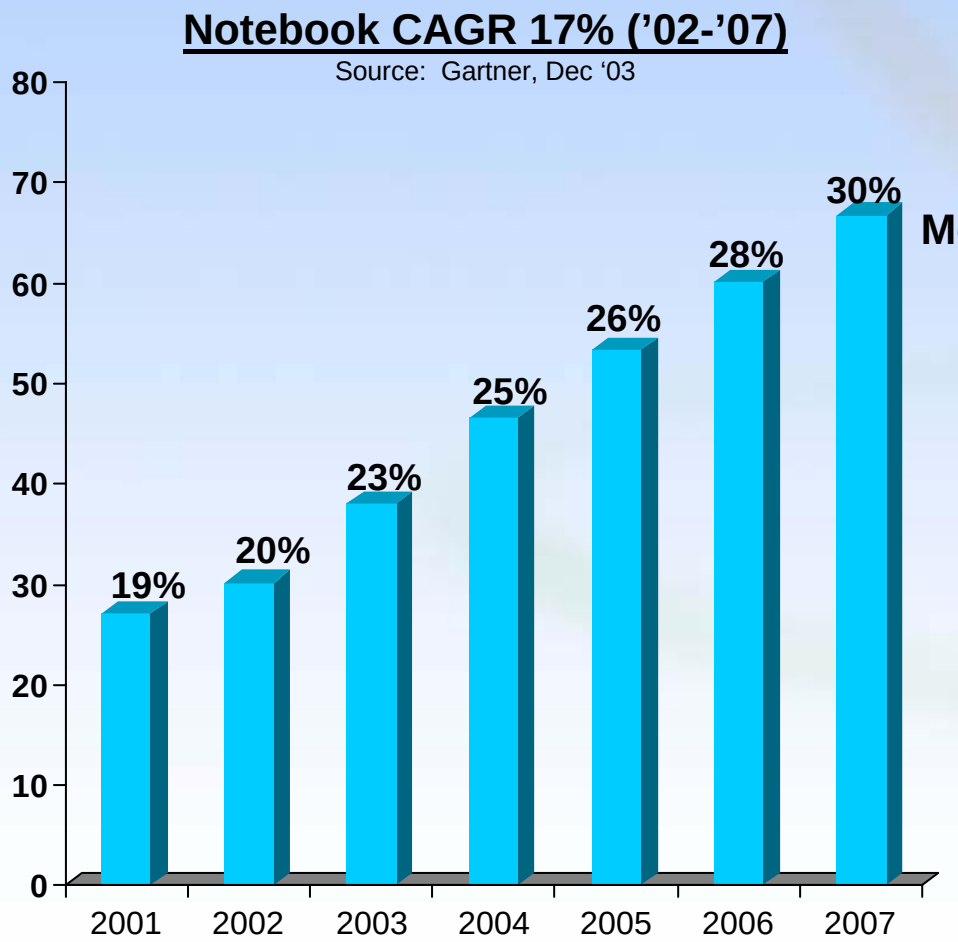
Simple Secure Wireless Connectivity

Best Performance in Form Factor

Innovative Form Factors for Your Life Style

Exceptional Battery Life

Mobility - - - > Growth

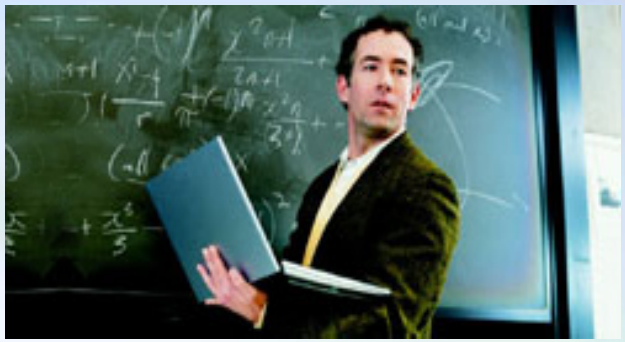


- Strong notebook growth in 2003
- Could point to faster growth trend long term
  - >20% y-t-y growth '02 to '03

Mobility systems expected to be ~60% of volume by 2006*

*Source: Intel analysis based on Gartner Qstats Q1-Q3'03

Mobility - - - > New Lifestyles



Usage Model Directions

Traditional mobile solution focus

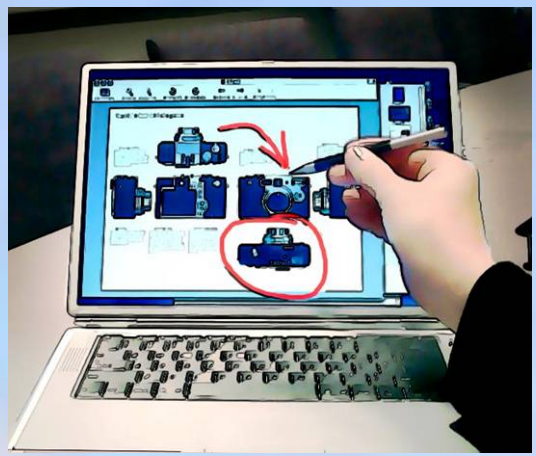
Grow notebook usage with solutions designed for consumers and broader base of business users

Digital Office

On-the-go Lifestyle

Mobile in the Digital Home

Digital Office Vision



Usages and Capabilities

- **Integrated Communications (VoIP, Collaboration)**
- **Extended Mobile Access (Always On)**
- **Simple Secure Wireless Connectivity**
- **Exciting New Form Factors (Pen Input, Camera Input)**
- **Location Based Computing (Location Input)**

2005 Digital Office – 14-15” Concept

14-15” All-in-one performance Thin & Light

Next gen Intel® Centrino™ Mobile Technology
EMA, SNS / OBR, VoIP
Camera, Array Microphones,
Fingerprint, Smartcard

Connectivity

WLAN 802.11abg, UMTS-GPRS, Bluetooth*

All-around mobile business notebook

* Other names and brands may be claimed as the property of others

Mobile Digital Home Vision

Usages and Capabilities

- **Integrated Communications (VoIP, Collaboration)**
- **Rich Digital Entertainment around the Home (TV, PVR, VoD)**
- **Exciting Form factors beyond clam shells (Camera Input)**

intel

2005 Mobile Digital Home 17” Concept

17” Widescreen portable

Next gen Intel® Centrino™ Mobile Technology
Computer-Media-Communication device
Media stack, BT Remote control, HD Audio
Camera, array microphones, VoIP Handset
TV display experience

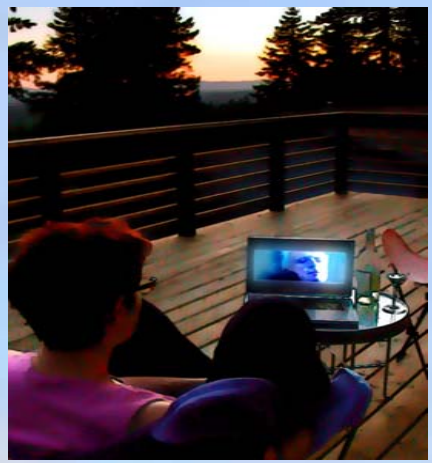
Connectivity

802.11abg, Bluetooth*

intel

Mobile Entertainment PC

On-The-Go Lifestyle Vision



Usages and Capabilities

- **Integrated Communications (VoIP, Voice, Video, Unified Inbox)**
- **Extended Mobile Access (Always-On, External Displays, WWAN)**
- **Simplified Network Selection**
- **Personal entertainment on road**
- **Location Based Computing**

2005 On-the-Go Lifestyle 12” Concept

12” Detachable tablet / laptop

- Next gen Intel® Centrino™ Mobile Technology
- Extended Mobile Access (EMA)
- Simplified Network Selection (SNS) / One Bill Roaming (OBR)
- Media Client, Camera, VoIP
- Fingerprint recognition

Connectivity

- WLAN 802.11abg, EDGE-GPRS, Bluetooth*

intel

Work around the office or around the world

Convergence in Mobile Notebooks

- **Computing: best performance**
- **Communications: Wireless (WLAN, WWAN, Bluetooth, WiMAX, UWB)**
- **Entertainment: Digital Video, TV, MP3, WMA, PVR**
- **Form factor: Clamshells, Tablets, New Portables**
- **Security: Biometrics, TPM, Smartcards, SIM, LT**

Agenda

- Mobility Is Happening
- Battery Life
- Energy Sources
- Energy Consumers
- Summary

Battery Life Background

- **Most Notebooks are measured with BAPCO's* MobileMark* 2002 benchmark**
- **Measures Performance and Battery Life for Productivity Workload – assumes typical usage system idle 80% and active 20% of time**
- **For future usage we need to assume two connected scenarios:**
  - **Today usage: sleep (not connected), active, idle**
  - **Always-on – low power (connected), active, idle**

Battery Life Innovations

- Intel® Centrino™ Mobile Technology platform improved Thin and Light platform battery life from under 3hr to > 4hrs w/6 cell battery
- Silicon innovations – Intel® Pentium® M processor, Chipsets
  - Dynamic Voltage Scaling; Aggressive Clock gating, Frequency scaling, Intel® 2D Smart Display Technology
- Platform Innovations – Displays, Power Delivery, HDD, ODD
  - Lower Power Displays, Display Power Saving Technology, Buffering Drives, More efficient Voltage Regulators

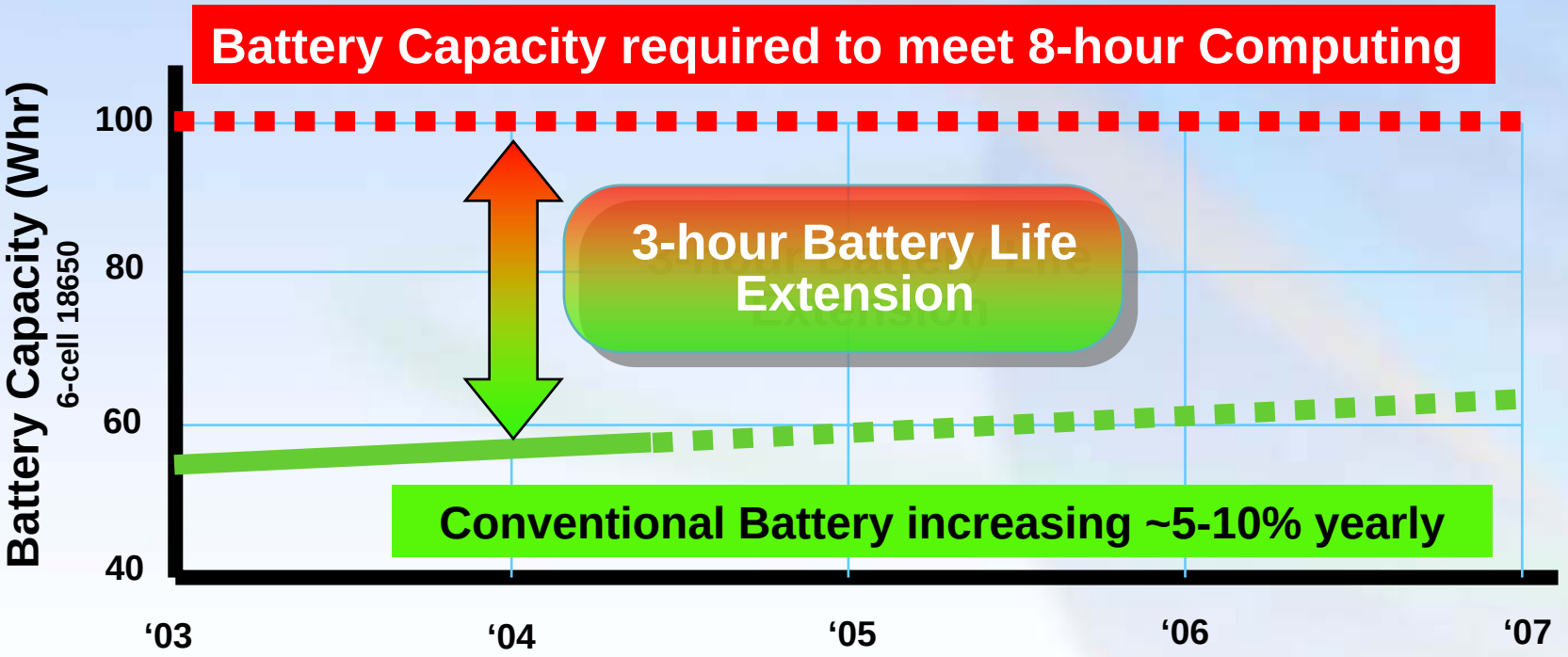
Longer battery life is desired as users want mobility

Agenda

- Digital Office Vision 2010
- Mobility Is Happening
- **Battery Life – Energy Sources**
- New Usage Models
- Summary

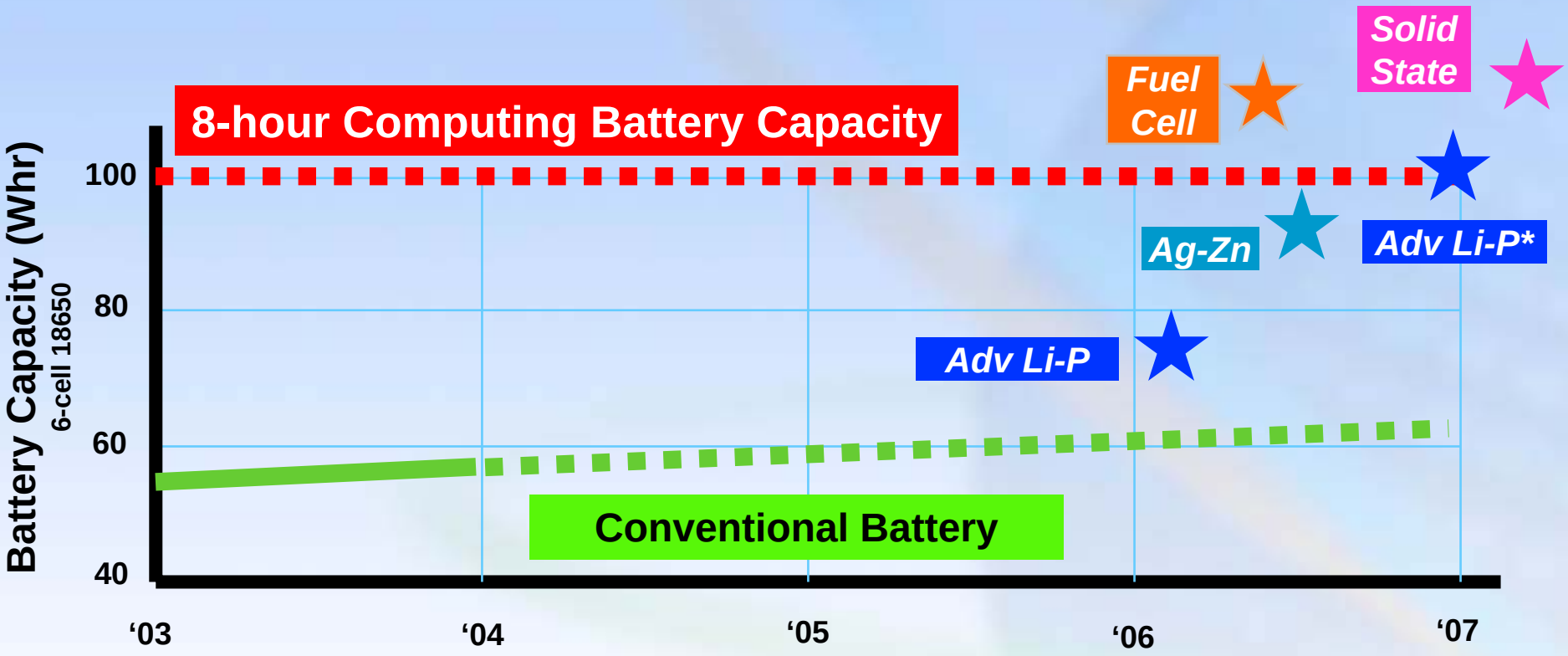
8-Hr Battery Life Challenges

$$\text{Battery Life (hr)} \approx \frac{\text{Input Power Capacity (Whr)}}{\text{Average Platform Power Consumption (W)}}$$



Large Gap for conventional battery to overcome

Emerging Battery Roadmap



Emerging technologies may bridge the gap

Battery Summary

Battery Type	Volumetric Energy Density (Whr / L)	Gravimetric Energy Density (Whr / kg)	Cost ($)	Cycle Life (80% charge retention)
Li-Ion	400	170	Baseline	500
Adv. LiP	600-800	180	Same	Same
Ag-Zn	600-800	200		Same
Solid State	800-1000	300		3x

Emerging battery technologies meet 8-hour computing target

Shorter Term Battery Life Solutions

- **Extended Packs, Drive Bay – E.g., IBM T40 (9 cell), Samsung, Toshiba*, etc can deliver 6+Hrs today**
  - **Heavier, Bulkier**
  - **Longer Charge Time**

- **Use Mini Notebooks – E.g., Sony TR3A, IBM X40* can deliver >7hr battery life today with extended packs**
  - **Compromise on Experience**
  - **Heavier, Bulkier**
  - **Longer Charge Time**

Longer Term Battery Life Solutions

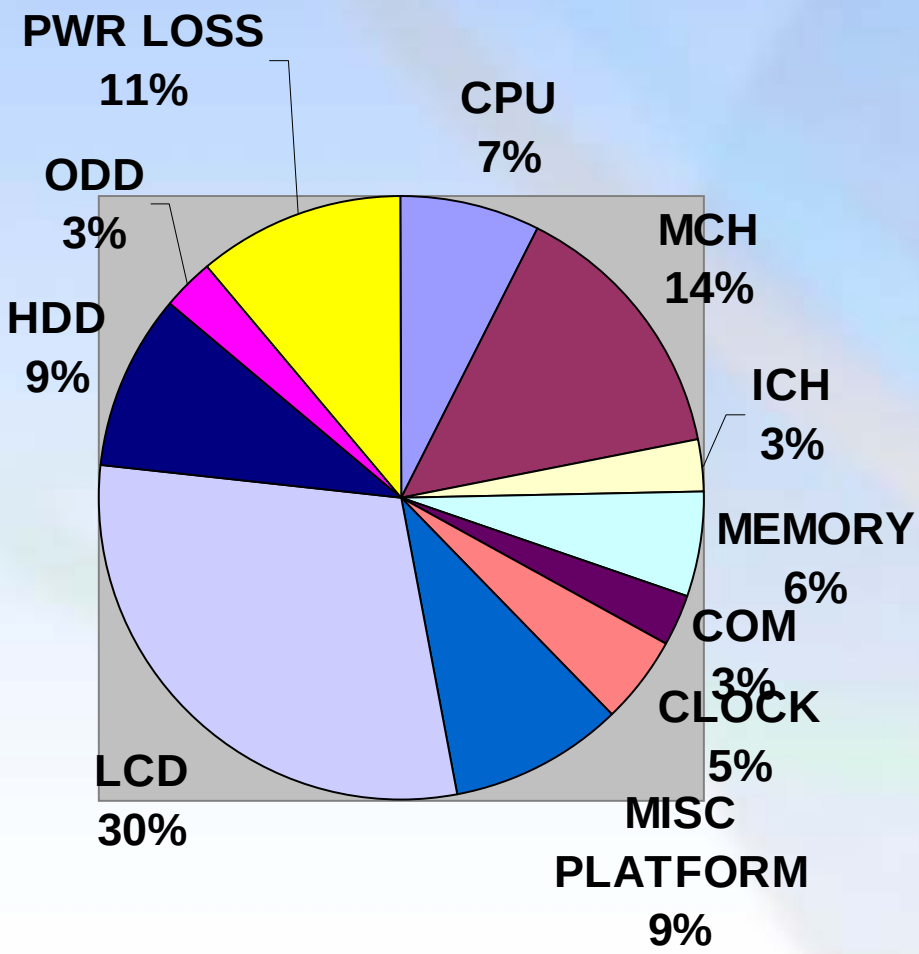
- **Fast Recharge Battery -10mins**
  - **New Chemistry**
  - **Smaller Capacity (50-70% of Li-Ion)**
  - **Heavier Adapters**
  - **Cost**
- **Fuel Cells (Hybrid Battery)**
  - **Trickle charge**
  - **Regulatory Issues**
  - **Bi-products – generate heat, water**
  - **Miniaturization required – pumps**

Both will require long qualification cycles

Agenda

- Mobility Is Happening
- Battery Life
- Energy Sources
- Energy Consumers
- Summary

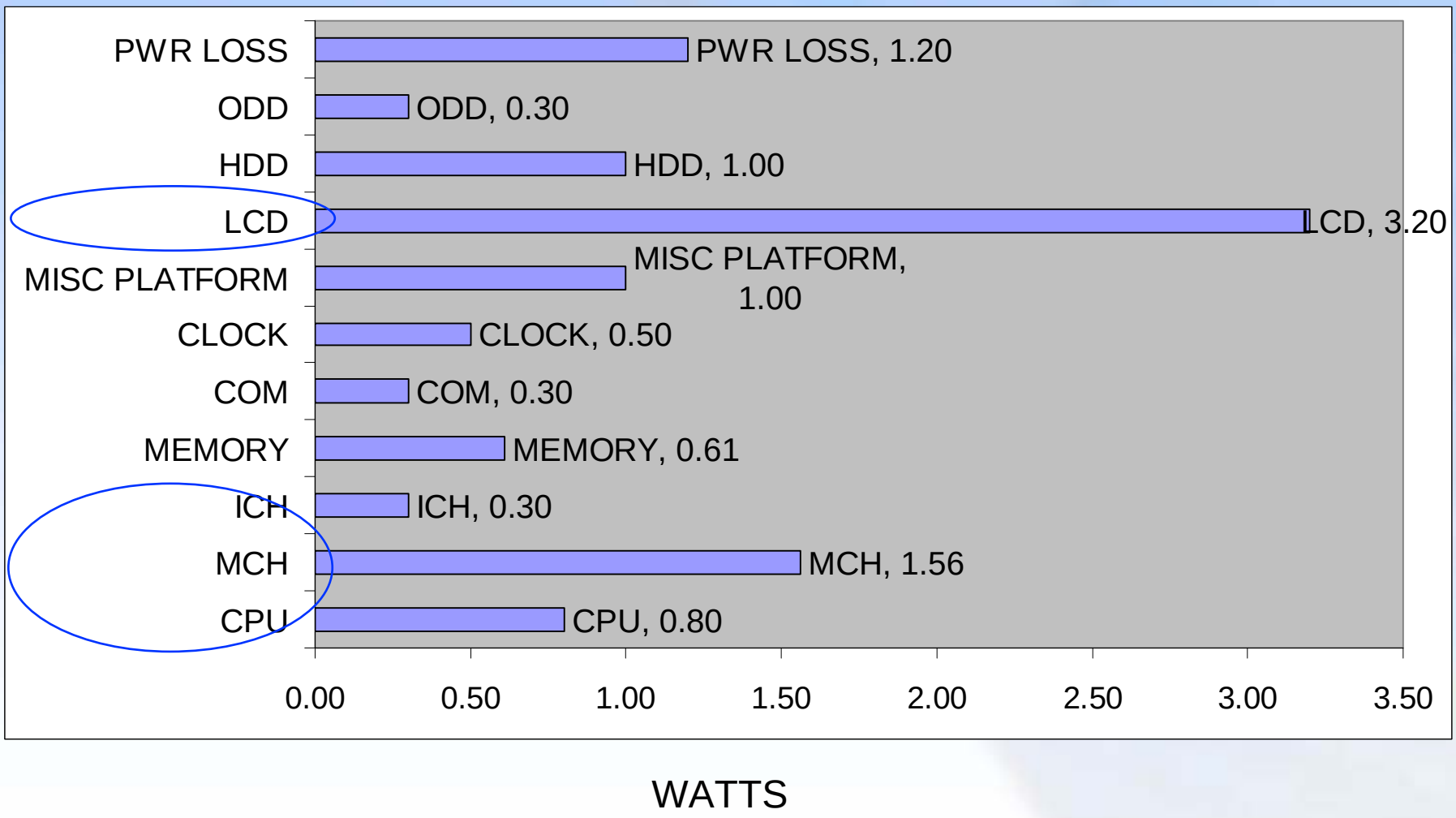
Average Power Contributors 2003 Platforms



Good Thin & Light Platform

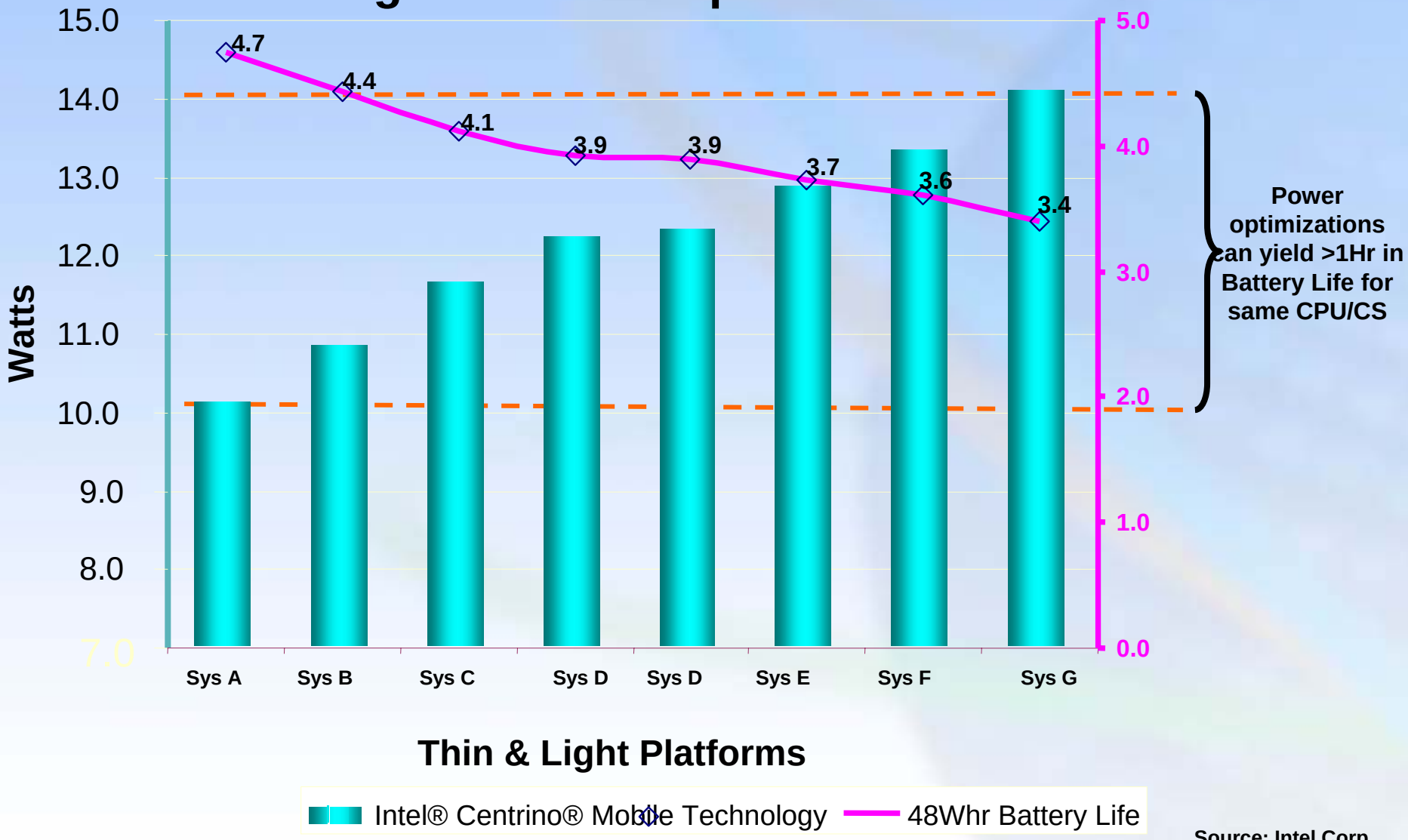
Source: Intel Corp.

Average Power Contributors 2003 Platforms



Source: Intel Corp.

Intel® Centrino™ Mobile Technology Thin & Light Platform Average Power Comparison



Source: Intel Corp.

Plenty of Opportunity to Improve Battery Life

LCD Display

- Current technology is based on Amophorous TFT, largely driven by conversions of TV LCD
  - Trending to higher power (4.5-5.5W Displays) for NB's
- New technology – Low Temperature Poly Silicon (LTPS)
  - Reduced power (2.8-3W), Thinner, lighter (less components), Brighter (let's more light thru – thus reduces Back light)
- Longer Term potential
  - OLED/PLED – eliminate backlight, but currently higher power
  - Flexible Displays – polymer based

Display Power Goals & Challenges

- **Key Areas to focus**
  - **Display subsystem - let more light thru with less energy**
  - **Back light - reduce or eliminate back light**
  - **Improve power delivery**

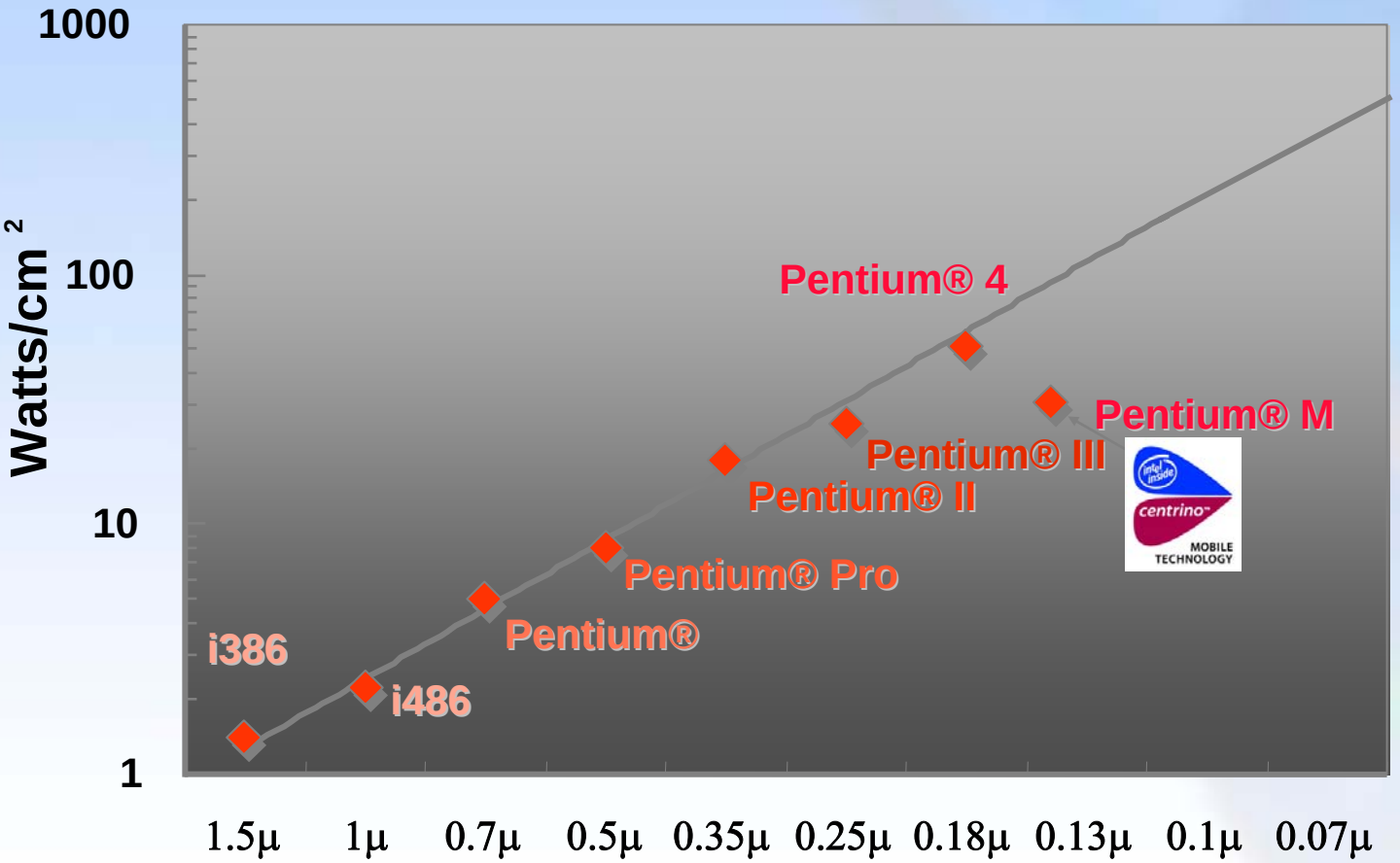
- **Challenges**
  - **User like higher resolution (XGA, SXGA+, QXGA, UXGA)**
  - **Bright screens (150-200+ nits) – note MM'02 uses 60 nits, some OEMS quote battery life at 30 nits**
  - **Larger displays (E.g., 14.4", 15.4" , 17")**

Other Display Power Reductions Opportunities

- Use camera or light sensor to detect ambient lighting to decrease or increase back light on Notebook
  - Can result in 0.5-1W reduction in average power
- User presence detect (UPD) – uses camera to detect user is present / absent or attention to control display or system
  - Can result significant savings >1-2W on typical usage

Intel® Pentium® M Processor – Makes Right Hand Turn

- **Lower Thermal Design Power – Thinner & Lighter FF**
- **Lower Average Power - Longer Battery Life**

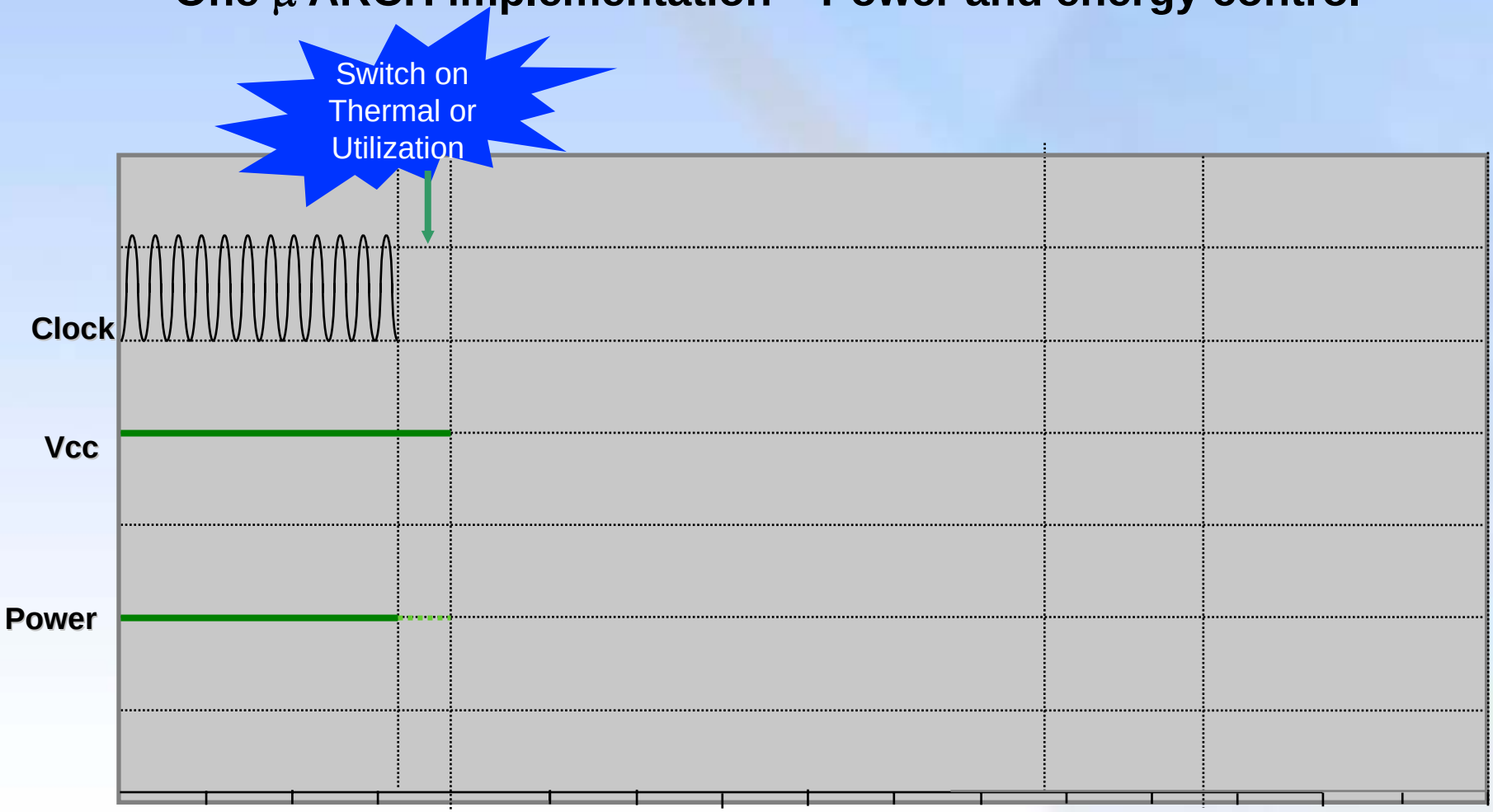


Intel® Pentium® M delivers high performance and best performance / watt

*"New Microarchitecture Challenges in the Coming Generations of CMOS Process Technologies" – Fred Pollack, Intel Corp. Micro32 conference key note - 1999.

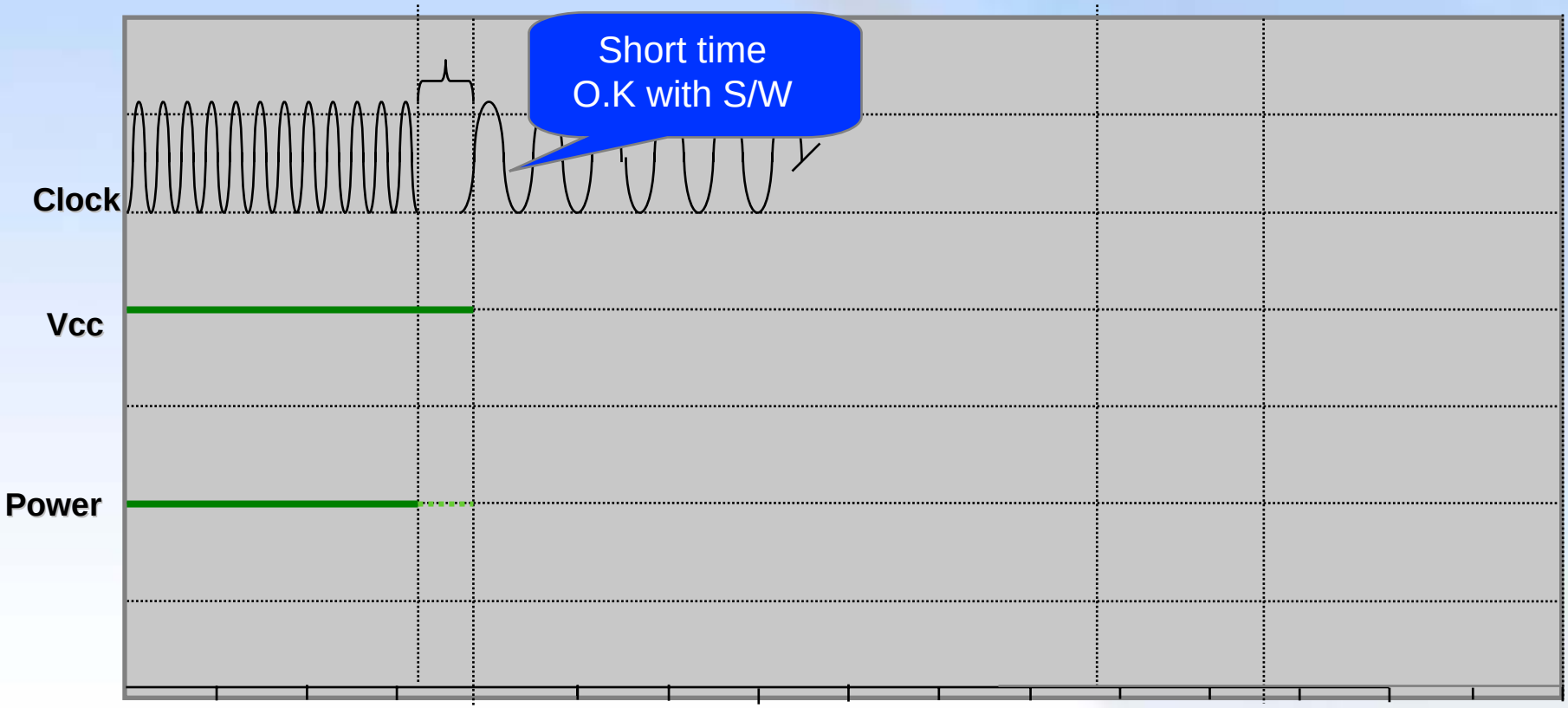
Dynamic Voltage Scaling (DVS)

- One μ ARCH implementation – Power and energy control



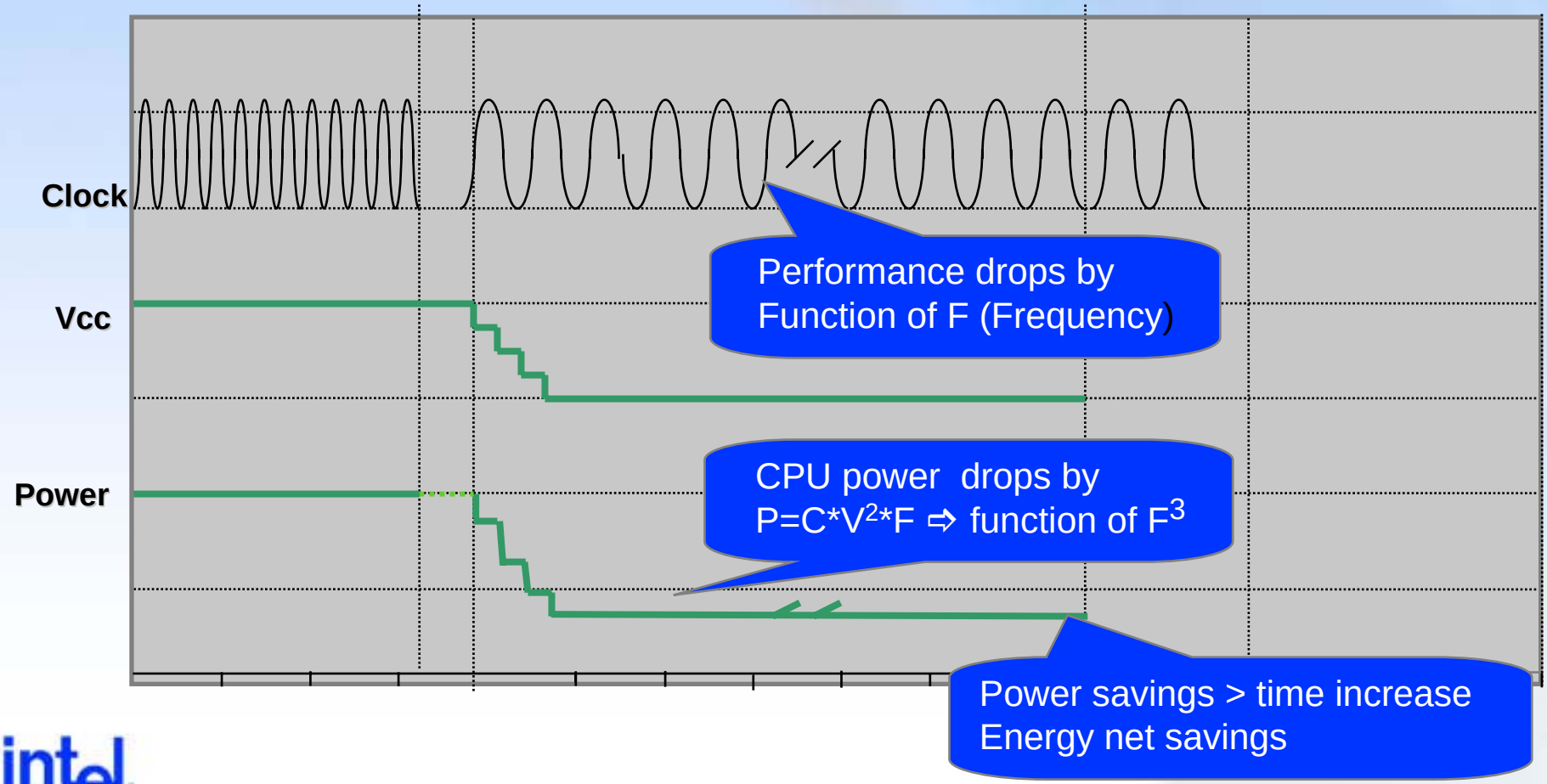
Dynamic Voltage Scaling (DVS)

- PLL relock at lower frequency at same Vcc
- Fast change – no user experience impact



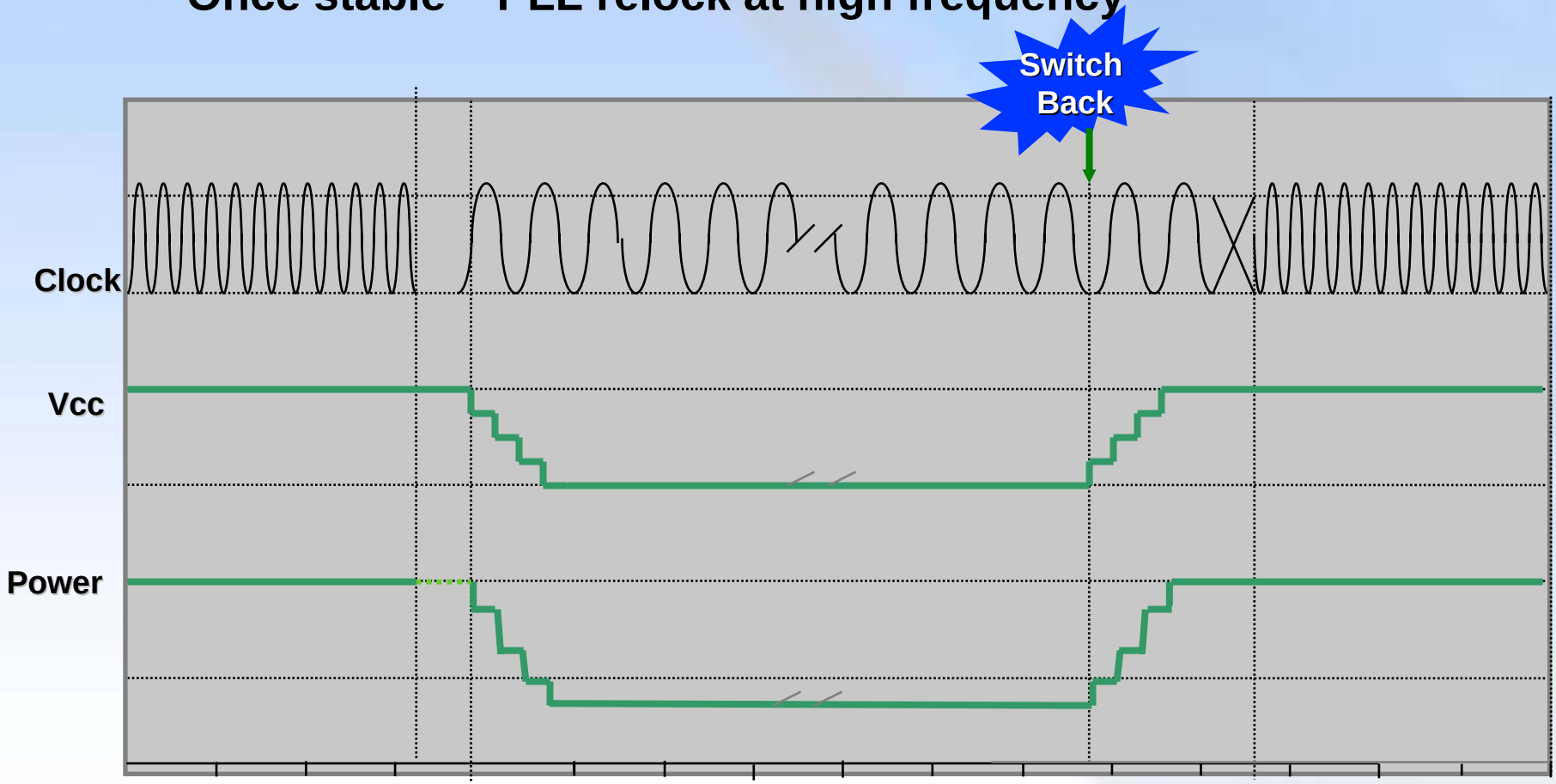
Dynamic Voltage Scaling (DVS)

- Vcc drops gradually while CPU active
- Power savings changes from linear to F^3



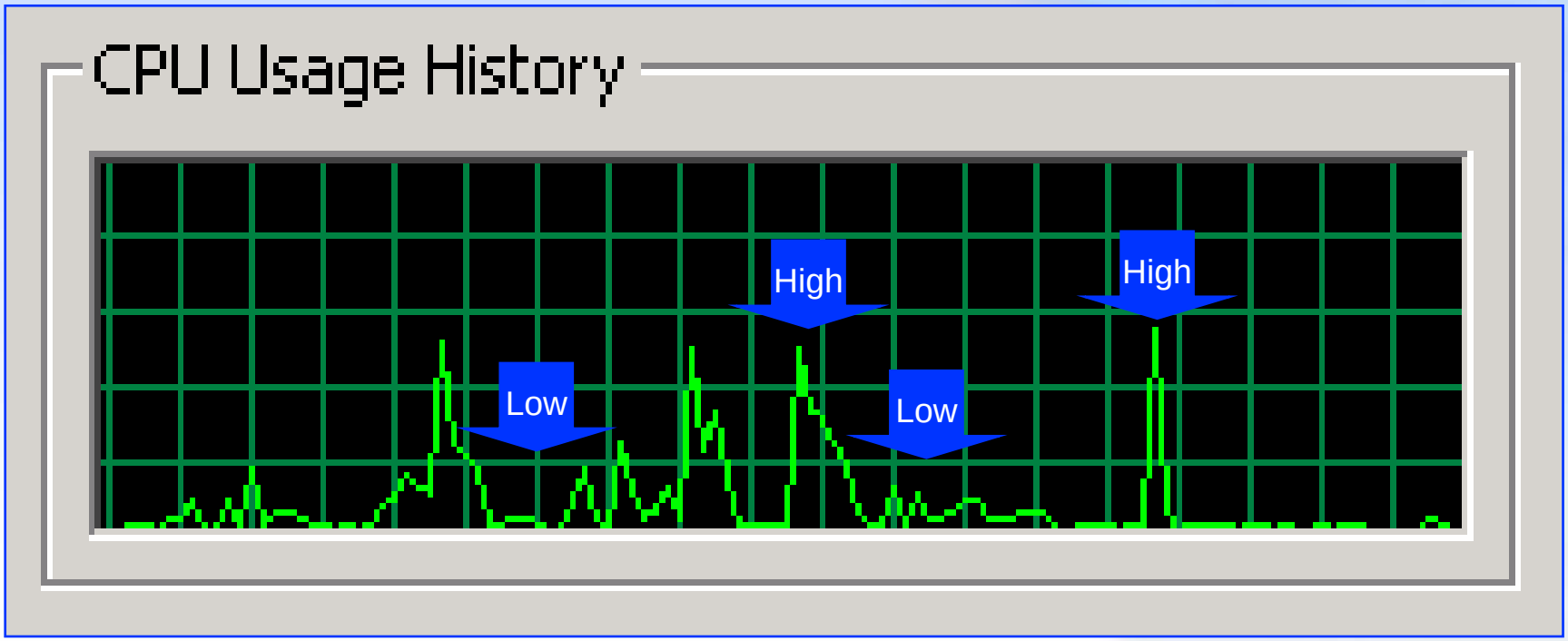
Dynamic Voltage Scaling (DVS)

- Vcc is ramped up increasing power
- Once stable – PLL relock at high frequency

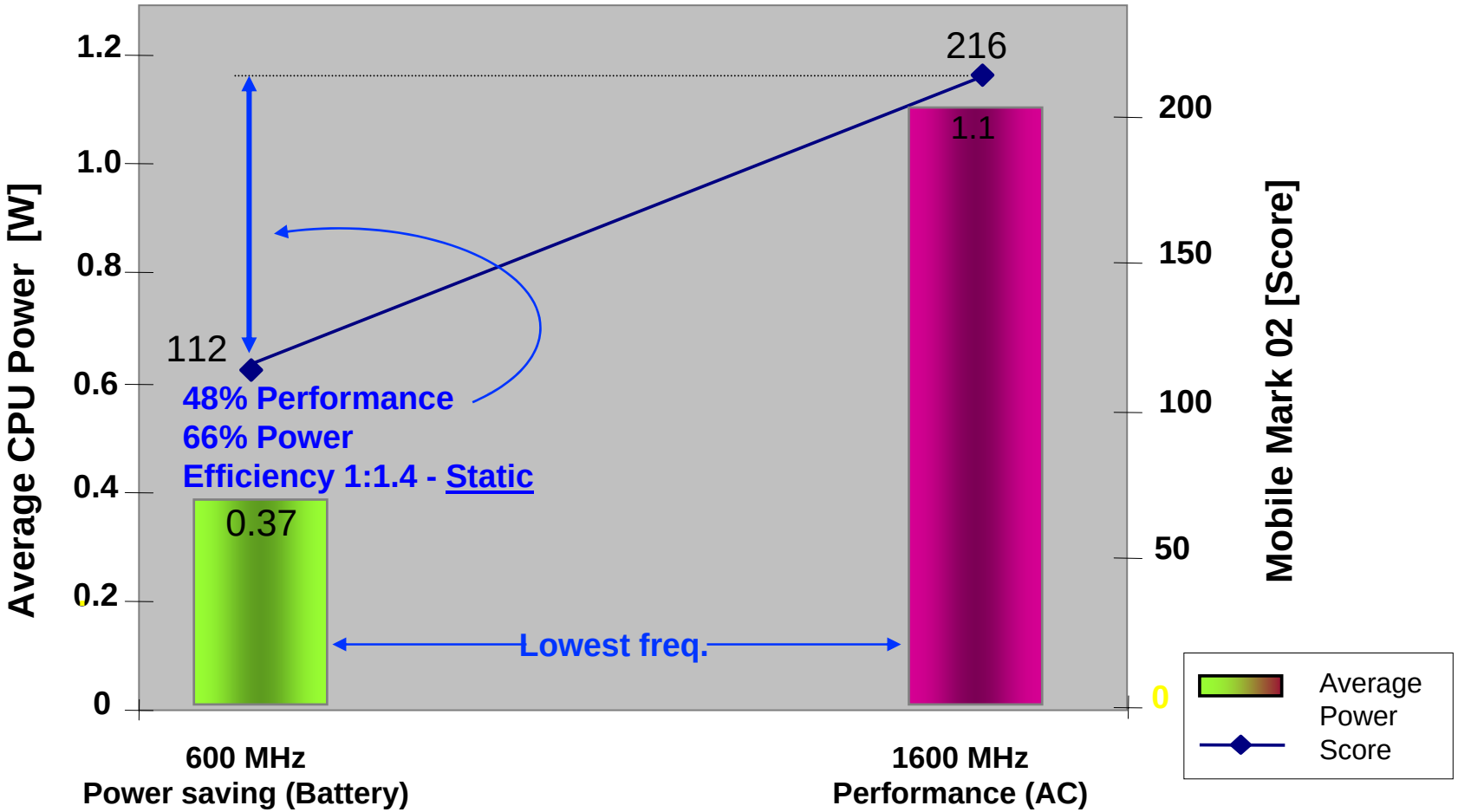


Adaptive Energy Control

- Applications have dynamic need - require high power high performance bursts
- Trade Average power vs. performance as needed
  - Driven by User thru Operating system ACPI (Max Battery, Max Performance or Adaptive - Average power control on the fly)

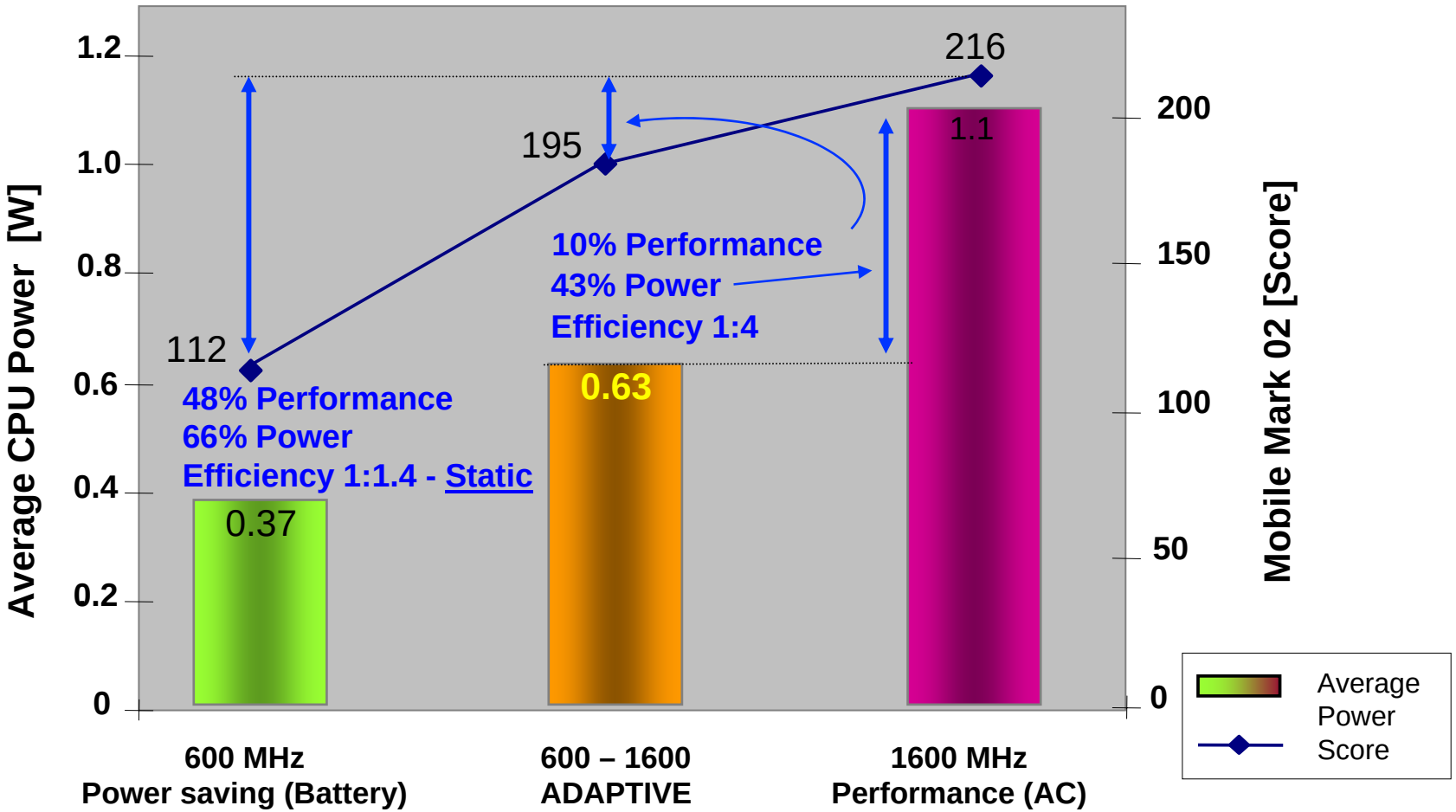


Average Power management on Thin & Light NB



Source: Intel Corp.

Average Power management on Thin & Light NB



Source: Intel Corp.

Agenda

- Mobility Is Happening
- Battery Life
- Energy Sources
- Energy Consumers
- Summary

Trends – Straining Battery Life

- Higher performance Si (General Purpose, Media, Graphics)
  - More Logic, Bigger Caches, Higher Speed Interconnect, Com
- Proliferating Usage - Always-Connected, Media Usage
- Better Displays - Bigger, Brighter, Higher Resolution
- Shrinking Si Geometries – Leakage dominates Idle power
- New operating systems – MS Longhorn, 3D User Interface

Call to Action

- Drive System Level Approach to increasing Battery Life
  - Newer Display Technologies
  - Device Performance States (ala DVS in Peripherals)
  - Lower power platform designs
  - Turn off devices when not in use
- Drive to address leakage power on all Silicon
- Drive low average power on all Si - CPU, Chipset, Graphics
- Drive software to be power state aware (e.g., remove loops)
- Drive development of higher density energy and fast renewable sources