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Corporate Technology

Green SW Engineering: Ideas for Including Energy Efficiency into your Software Projects

ICSE 2009 VANCOUVER

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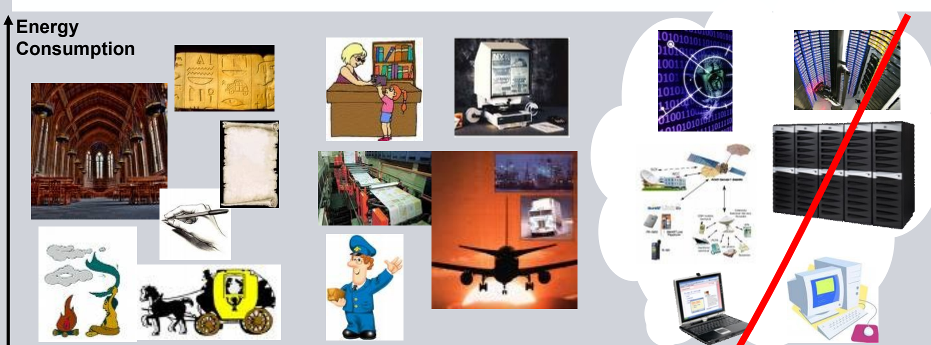
Information Processing History – from Stones to the Pervasive Cloud



Storage	Physical (stone, paper)	Physical (paper)	Digital physical (tapes, disks, DVDs)
Copying	Hand writing	Printing machines	Virtually by computers
Transport	Physical	Physical (paper by vehicles)	Virtually by Internet
Delivery	Physical	Physical (paper by vehicles)	Virtually by internet

4000 BC	1500 BC	1500	1600	1800/1900	1938	1981	1990
Lettering	*Pergament*	*Printing*	*Trains*	*Cars, Trains*	*Computer*	PC	*„Internet“, WWW*

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Agenda

- Scope and Introduction
- HW/ SW Architecture Energy Measures
  - Network Layer
  - Hardware Layer
  - Operating System Layer
  - Middleware Layer
  - Application Layer
- Summary and Key Takeaways

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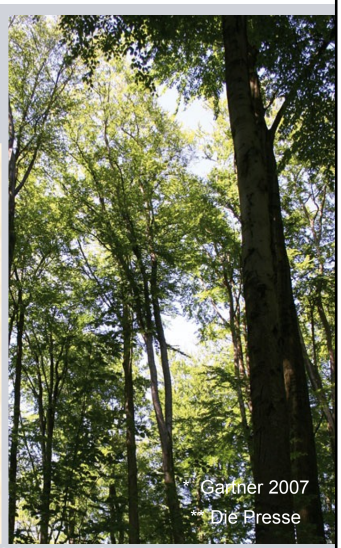
IT contributes 2% of world-wide CO_2…

- Information procession radically changed over time
- Functionality and performance have been permanently increased, **but** energy consumption and CO_2 contribution were not transparent to provider and user

Samples from press:

- 2006 (US): US IT consumes 60 billion kWh (1,5% of total US electricity) or more than all US color TVs!
- Worldwide IT CO_2 contribution is 2% that's same as the contribution of all airplanes*
- A Google search needs on avg. the same energy as a 11W energy saving lamp in one hour (11 Wh)
- 4 virtual players (characters) in the virtual world „Second Life" produce the same CO_2 contribution as one real human**
- 40% of energy needs from banks already IT related
- **IT energy consumption is growing at 12% annually**



Start TODAY to make your Software Energy Efficient

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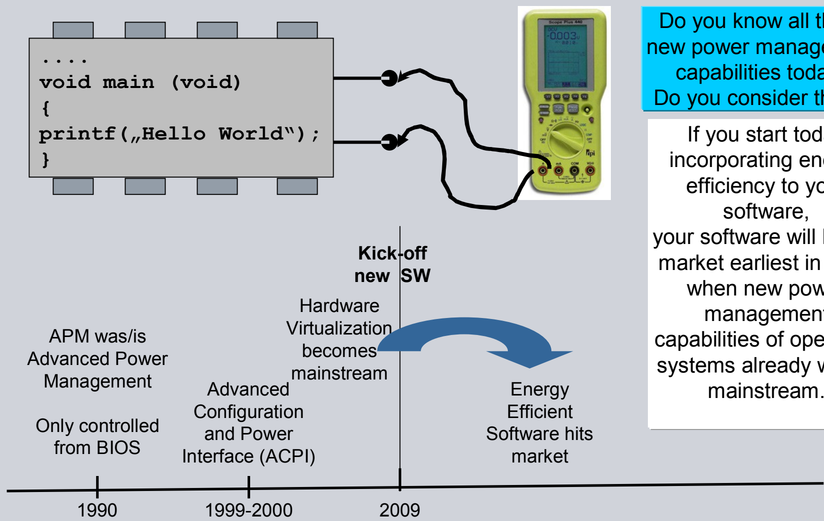

Do you know all these new power management capabilities today? Do you consider them?

If you start today incorporating energy efficiency to your software, your software will hit the market earliest in 2010 when new power management capabilities of operating systems already will be mainstream.

What can we do from a Software Engineering Perspective?

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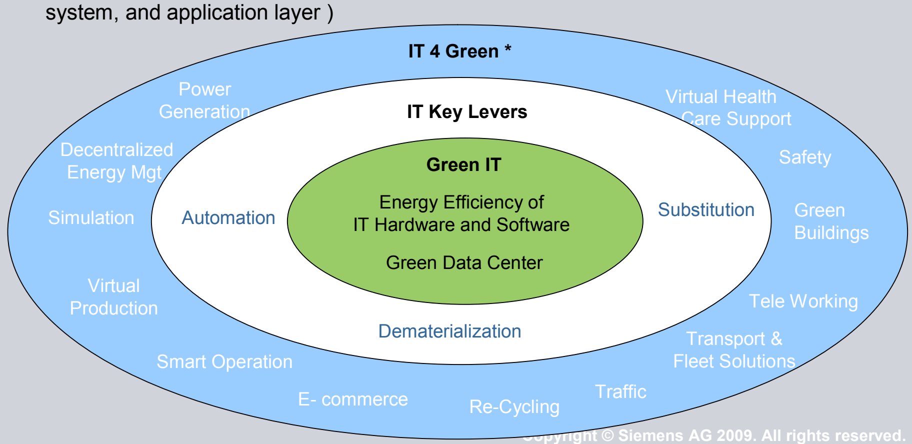
This talk focuses on **"Software Energy Efficiency"** as part of **Green IT**, **aiming to:**

- increase awareness and transparency of IT system energy consumption
- give ideas for including energy efficiency to your software projects (hardware, operating system, and application layer)



Green IT:
…CIO's "feel" responsible …

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"For every $ spent on server hardware, add the same amount for power and cooling during lifetime!"

- Is "energy" a purchase criteria for your IT?
- It might be for your car… but IT?**

Get transparency of energy consumption
59% of CIO's feel responsible for the topic of Green IT

90% of the questioned CIO's did not know the energy consumption of their IT*

* Information from Experton
** Average hardware prize vs. energy costs over 3 years, Gartner: Why "Going Green" will become essential for data centers 10/2006

Why haven't we looked at Energy Efficient IT before? …. a try to explain…

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Executive Focus:

earnings = income – expenses

Goal: → Minimize expenses

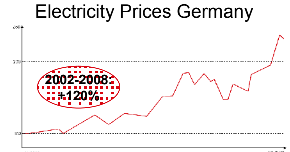
Investment costs (CAPEX):
- e.g. IT equipment, SW development, …

Operational costs (OPEX):
- facility cost (cooling, rent, ..)
- energy consumption (cooling, light)
- maintenance and spare parts
- human personnel …

Today, IT operation energy cost are hidden.
Therefore, it's hard to argue to minimize TCO by buying new energy efficient hardware or develop energy efficient software. Increasing energy costs, increase awareness…

Increasing energy costs motivate for energy efficient IT

Electricity Prices Germany



Source: VIK (Adapted)

- Electricity prices volatility (Germany: +22% 2008)
- Energy consumption increases (+7% China`07)
- Crude oil price volatility (+400% 1996-2008)

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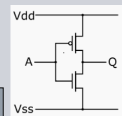
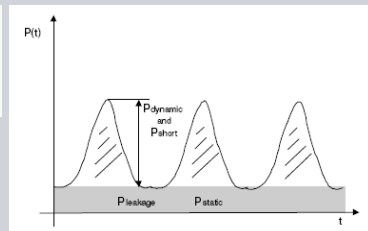
Why IT Systems Consume Energy?

Most information today is processed by integrated CMOS circuits.

CMOS circuit power dissipation:





~ 80% | ~ 20%

$P_{total} = P_{dynamic} + P_{short} + P_{leakage} + P_{static}$

Measures

Optimize Software | Switch-off when possible

$P_{dynamic}$ … dynamic power consumption about (~ 80%)

P_{short} … short-circuit power consumption, the input rise/ fall time is greater than null, the pull-down and the pull- up are both on for a short period of time. During this time, there is a resistive path between power and ground. (~ 10%)

$P_{leakage}$ … leakage power is mainly caused by two phenomena: diode leakage current due to the reverse saturation currents in the diffusion regions of the PMOS and NMOS transistors; sub-threshold leakage current of transistors which are nominally off (~ 10%)

P_{static} … static current between VDD and GND caused by defect CMOS element (~ 0% without defect)

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HW/ SW Architecture and Energy Efficiency Measures

IT Application HW/ SW Architecture and Network Infrastructure

- Application
- Service
- Middleware
- Operating System
- Device Hardware
- Network

Layer Specific Measures

Cross-Layer Application

Domain Measures

Consider use of network resources

Pro:
+ Detailed knowledge of application energy requirements and measures
+ Most effective energy management possible, using context

Contra:
- energy management conflicts with other applications, because complexity
- compatibility and portability issues
- more expensive

Pro:
+ Closer to hardware and saving measures
+ Measures transparent to higher layers
+ Cheaper to achieve

Contra:
- no knowledge about application profile
- avg. measures cannot utilize the possible savings potential

Network Layer
Network Energy Consumption (last Mile)

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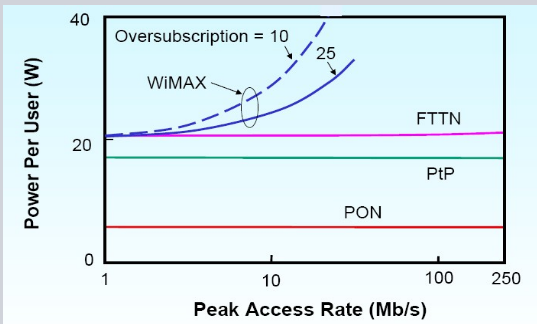
Power Consumption in Access Networks



FTTN	Fiber-to-the-Node Optical network to the neighborhoods
FTTH	Fiber to the Home
PON	Passive Optical Network PONs use shared fiber and passive light transmission to bring the data stream into the individual links to each customer
PtP	Point to Point one dedicated fiber for each user in the access network

- Wireless access consumes more energy than optical access
- PON FTTH is “greener” than FTTN

Rodney S. Tucker; "Energy Consumption in IP Networks", ARC Special Research Centre forUltra-Broadband Information Networks (CUBIN) University of Melbourne

Network Layer
Summary of Energy Efficiency Measures

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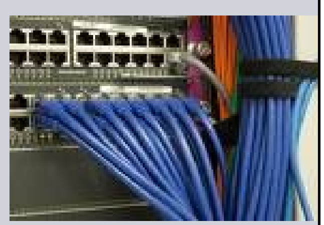
Layer Specific Measures

Energy consumption is currently dominated by the access network (compared to average consumption per user in the Internet)

- Key strategies for efficient network design
- Control energy in the access network (e.g. sleep mode in modems)
- Reduce the hop count (i.e. “agile” optical bypass)
- Caching and content distribution networks
- Select energy efficient technology if feasible

Cross-Layer Measures

- Increase awareness that every network require energy and use request only if required. Prefer replicated short hop end points



Hardware Layer
Energy Consumption Distribution Drill-down (1)

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e.g. Power Supply Units

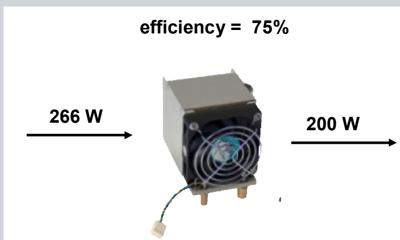
A typical cheap server power supply has an efficiency of:

75-85%: 400W ~ 60 – 100W wasted power

A high-end server power supply, operated optimally, has an efficiency of

95%: 400W ~ 20W of wasted power

Therefore, it's very important to chose power supplies very carefully and use the right one to operate it at optimal operation point.



efficiency = output / input

e.g. 24/7 operation this power supply waste is per year: 66*24*365 = ~578 kWh

e.g. a fridge needs ~300kWh

So, that bad power supply wastes 115 EUR energy and 356 kg CO2 which equivalents a care drive CO2 output of 2636 km (1)

Hardware Layer
Energy Consumption Distribution Drill-down (2)

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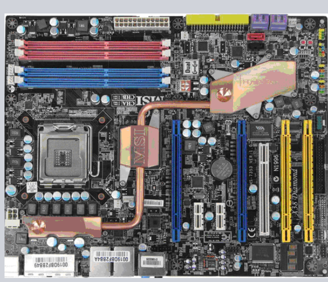
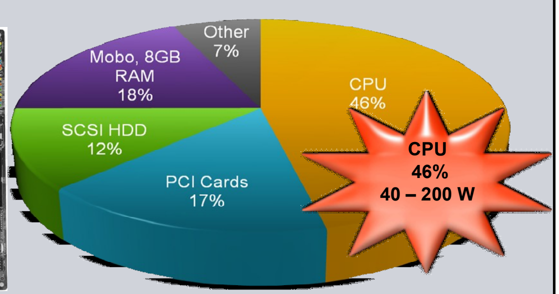
About 160W of a typical dual 450W 2U server are wasted, that are 35%!

Source: Intel Server Products Power Budget Analysis Tool
http://www.intel.com/support/motherboards/server/sb/cs-016976.htm





Processor power management represents the best opportunity today

The Green Grid Opportunity: Decreasing datacenter and other IT energy usage patterns
www.thegreengrid.org

Hardware Layer
Energy Consumption Distribution Drill-down (3)

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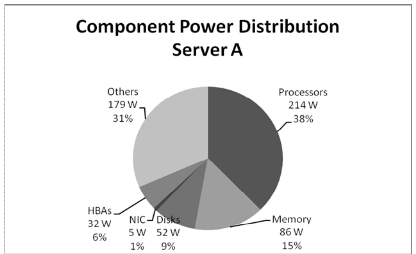
Power consumption distribution changed over the last years:

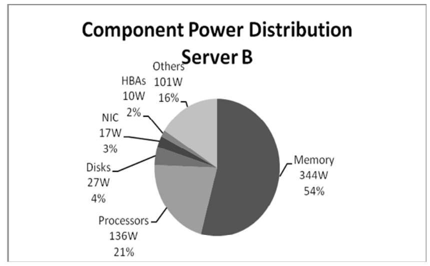
2005 two-socket dual-core server
idle power consumption **568 watts**



32 DIMMs of 2GB DDR RAMs

4 hard disk of 36GB 15k RPM 3.5 SCSI

Component power distribution,
2008 four-socket quad-core server
idle power consumption **635 watts**



32 DIMMs of 4GB DDR RAMs

4 hard disks 72GB 15k RPM 2.5 Ser. Attach. SCSI (SAS)

For the same application requirements the newer over provisioned system needs more energy!
Reason: Higher idle energy consumption and unused computation power.

Hardware Layer
Advanced Configuration and Power Interface (ACPI)

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ACPI Processor States:

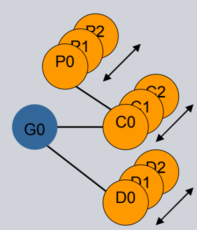
G- States… define global states
G0.. Working G1… sleeping, G2 soft-off, G3…mechanical off

C-States … define incremental levels of processor idle
C0 .. Processor active, C1,C2,C3, … lower power idle states

P-States… define level of processor in operation performance
P0… most performance, P1,P2,P3, … less performance/ power states

D-State… define levels of device in operation idle states
D0… full performance, D1,D2,D3, .. Lower idle power device states

T-States… to throttle power consumption by reducing clock rate
T0… full speed, T1, T2, T3 …. reduced clock rates
T-States are used if processor does not support P-States



Info: View not complete!

ACPI also supports thermal state management.

Hardware Layer
Scale-out vs. Scale-up

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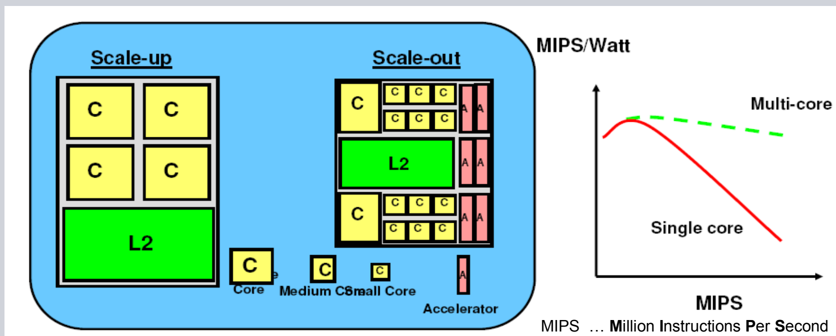
$P_{dynamic} = C_{eff} * V_{dd}^2(f) * f$

C_{eff}: linear impact; $V_{dd}^2(f)$: quadric impact; f: linear impact

Lower **f** allows lower $\mathbf{V_{dd}}$!!!

But, only if software (parallel) and dynamic power management (switch off idle cores) are aware of the new paradigm.

Power dissipation through frequency (**f**) scale-up became the limiting factor in processor design.



MIPS … **M**illion **I**nstructions **P**er **S**econd

Hardware Layer
Consolidation via Hardware Virtualization
Reduction of overall Idle Power Consumption

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Physical Infrastructure

e.g. mail server, file server, web server, access server

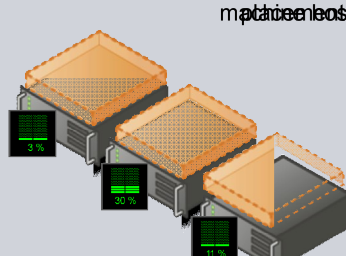
Performance data collected to identify consolidation candidates

Physical servers converted to virtual machines or consolidated

Prioritized report of consolidation candidates

Intelligent placement of Virtual Machines on optimal hosts

Performance data of target VM hosts for virtual machine hosts



Virtual Machine Hosts

Hardware Layer
Summary of Energy Efficiency Measures

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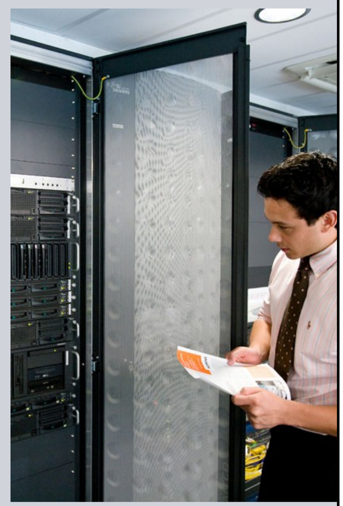
Layer Specific:

- Consolidation through hardware virtualization
- 2.5-inch disk drives instead of 3.5-inch drives (with low revolution 10 000 RPM or even 7200 RPM)
- Check power consumption of RAM components
- Dynamic Power Management Capabilities (ACPI, processor and idle management, configurable high performance vs. low power components, ..)
- Efficient cooling (avoid active cooling if possible)
- Power/ Energy metering support

Cross-Layer:

- Consider application best practice hardware guidance (great vendor tools available)
- Hardware optimization for app. domain (multi-core, 64bit, special processors, …)
- Optimize hardware for application profile (low power discs, clock down machines)



Operating System Layer
Minimizing Processor State (by OS Power Policy)

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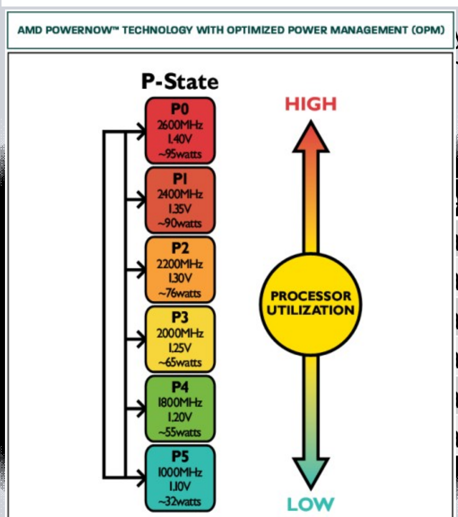
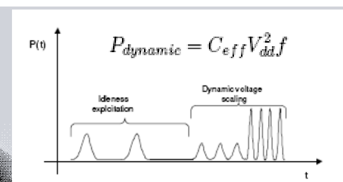
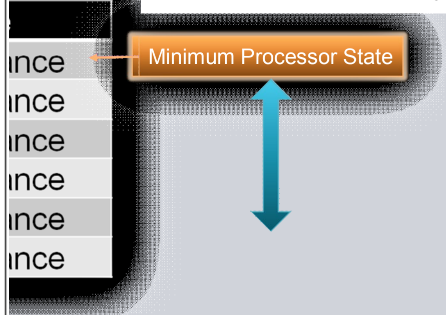


http://www.amd.com





Operating System Layer
Keep Background Activity at Minimum Level

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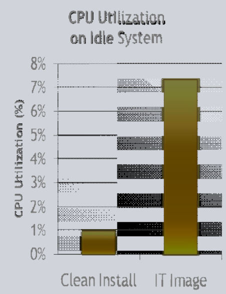
Processor performance is so high, that idle dominates almost all use scenarios for client systems

→Reducing idle power is key to reduce energy consumption

- Remove (or at least deactivate) unused background tasks or services
- Optimize (coordinate block execution) background tasks at macro level, to increase standby times:
  - defragmentation, indexing tasks,
  - virus scanning, backup, …
- Periodic background activity increase system power consumption
- Very frequent events impact processor and chipset power
- Long-running infrequent events prevent the system from idling to sleep
- Implement Power Management APIs also for background processes



Operating System Layer
Exploiting Idle Activity – Optimizing Timers

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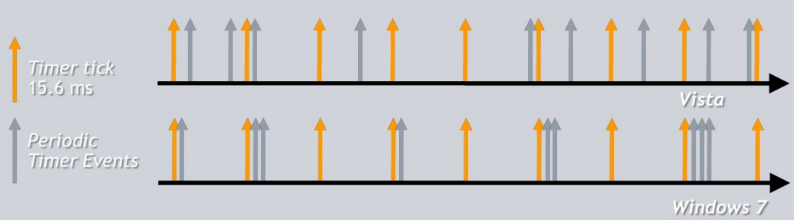
e.g. specific improvements Windows 7:

- Eliminate TCP DPC timer on every system timer interrupt
- Reduce frequency of USB driver maintenance timers
- Intelligent Timer Tick Distribution (ITTD)
- Timer Coalescing:
  - New timer coalescing API enables caller to specify a tolerance for due time
  - Enables the kernel to expire multiple timers at the same time



Operating System Layer

Windows Power Management Functions (Overview)

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Power Management Functions

The following functions are used with power management.

Function	Description
CallNtPowerInformation	Sets or retrieves power information.
CanUserWritePwrScheme	Determines whether the current user has sufficient privilege to write a power scheme
DeletePwrScheme	Deletes the specified power scheme.
EnumPwrSchemes	Enumerates all power schemes.
GetActivePwrScheme	Retrieves the index of the active power scheme.
GetCurrentPowerPolicies	Retrieves the current system power policy settings.
GetDevicePowerState	Retrieves the current power state of the specified device.
GetPwrCapabilities	Retrieves information about the system power capabilities.
GetPwrDiskSpindownRange	Retrieves the disk spindown range.
GetSystemPowerStatus	Retrieves the power status of the system.
IsPwrHibernateAllowed	Determines whether the computer supports hibernation.
IsPwrShutdownAllowed	Determines whether the computer supports the soft off power state.
IsPwrSuspendAllowed	Determines whether the computer supports the sleep states.
IsSystemResumeAutomatic	Indicates the current state of the computer.
ReadGlobalPwrPolicy	Retrieves the current global power policy settings.
ReadProcessorPwrScheme	Retrieves the processor power policy settings for the specified power scheme.
ReadPwrScheme	Retrieves the power policy settings that are unique to the specified power scheme.
RequestWakeupLatency	Specifies roughly how quickly the computer should enter the working state.
SetActivePwrScheme	Sets the active power scheme.
SetSuspendState	Sets the system suspend state.
SetSystemPowerState	Suspends the system by shutting power down.
SetThreadExecutionState	Enables applications to inform the system that it is in use.
WriteGlobalPwrPolicy	Writes global power policy settings.
WriteProcessorPwrScheme	Writes processor power policy settings for the specified power scheme.
WritePwrScheme	Writes policy settings that are unique to the power scheme.

Operating System Layer

Summary Energy Efficiency Measures

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Layer Specific

- **Shut-down screens instead of using screen savers**
- Do not block screen blanking if not really required
- Use customer profiles of OS for dynamic adapting power management
- State of the art OS idle state exploitation (interrupt filtering, timer optimization, network stack intercepting)
- Use only certified drivers for energy management (to allow idle states)
- Use only required services and background processes

Cross-Layer:

- Use power management APIs within applications (best practices sharing, …)
- Dynamic application specific power management adaption
- Optimize execution of runtime environments and virtual machines (e.g. garbage collection)

Middleware Layer
Protocol Impact on overall Energy Consumption

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Communication protocols connect peers. Therefore, energy is consumed at each peer involved in the communication loop (sender, gateways, proxies, receiver).
→ **less communication actions, less energy consumed.**

Therefore,
- avoid broadcasting where possible
- reduce number of parties involved in communication
- reduce amount of keep-alive messages where possible
- replace polling by publish subscribe communication (especially check new firewall friendly http tunneling layers)
- there are new service bus concepts, which allow two way communication on http-layer without polling – by e.g. simulating long „downloads“ instead of polling every second.

Middleware Layer
Cloud Platforms a new Energy Efficiency Opportunity

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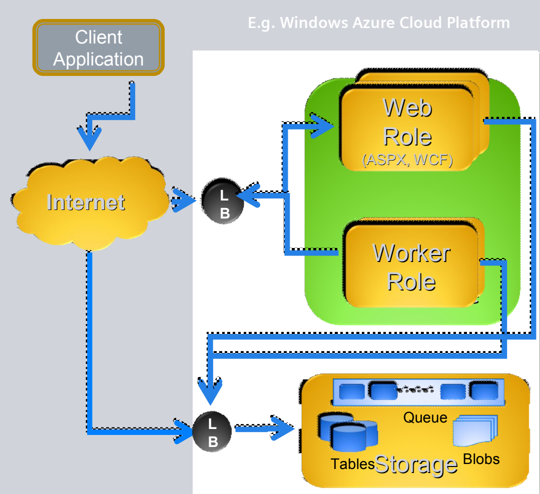
Cloud Platforms (e.g. Windows Azure or Google App Engine, …) are managed at big scale at high utilizations rates.
Therefore, Internet applications can be operated more energy efficient than on your own on-premise environment.

These cloud platforms are designed to scale-out vs. scale-up, which allows better dynamic power management,
but requires applications do be designed for.



Middleware Layer
Tradeoff between Compressed or Raw Data Transfer

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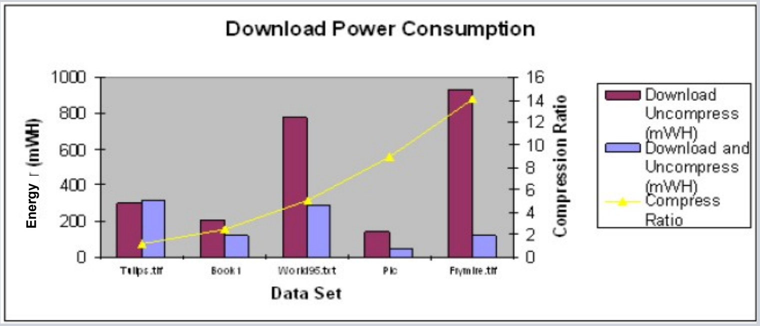

e.g. WLAN at Notebook utilizing a backend service

Problem: Long transfer time, long processor operation time

- compression ratios greater than 3.0x uploading/downloading compressed data provides better energy savings than uncompressed data at the sender
- compression ratios lower than 1.2x uploading/downloading raw data provides better energy savings than compressed data at the sender

Middleware Layer
Summary Energy Efficiency Measures

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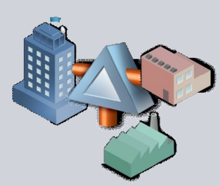
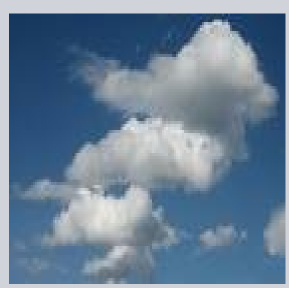
Layer Specific:

- Tradeoff between bandwidth and latency vs. energy consumption
- Tradeoff between compressed or raw data transfer
- Energy impact of communication protocols (information model, communication model)
- Caching and geo-redundancy for media distribution networks

Cross-Layer:

- Consider Cloud Platforms for energy efficient Internet applications
- Middleware support for client-side data caching
- Support idle exploitation of clients by filtering application requests





Application Layer
SPECpower_ssj2008

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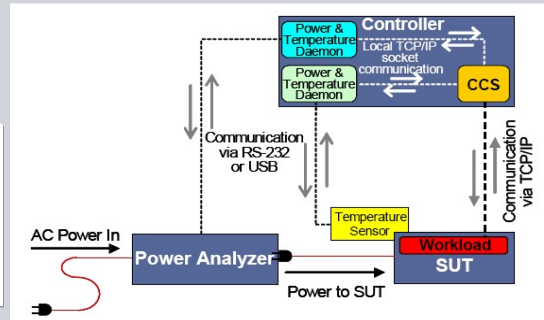
SPECpower_ssj2008 is a benchmark product developed by the Standard Performance Evaluation Corporation (SPEC) www.spec.org

Approach:

Compare performance with power consumption at different target load level including idle running Java server benchmarks.



∑ssj_ops / ∑power =
The overall score of the SPECpower_ssj2008 benchmark calculated from the sum of the performance measured at each target load level (in ssj_ops) divided by the sum of the average power (in W) at each target load including active idle.

Application Layer
SPECpower_ssj2008

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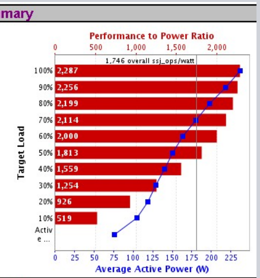
Benchmark Results Summary

Performance: Target Load	Performance: Actual Load	Performance: ssj_ops	Power: Average Active Power (W)	Performance to Power Ratio
100%	99.5%	541,345	237	2,287
90%	90.4%	492,017	218	2,256
80%	80.0%	435,393	198	2,199
70%	70.0%	380,801	180	2,114
60%	60.2%	327,674	164	2,000
50%	50.2%	273,097	151	1,813
40%	40.2%	218,697	140	1,559
30%	29.7%	161,721	129	1,254
20%	20.2%	109,761	119	926
10%	10.0%	54,213	105	519
	Active Idle	0	75.6	0
			∑ssj_ops / ∑power =	**1,746**

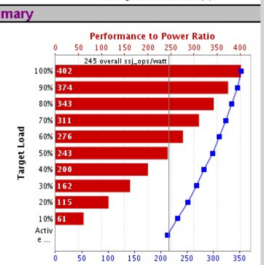


Results can be published at www.spec.org

Sample of an energy efficient machine

Benchmark Results Summary

Performance: Target Load	Performance: Actual Load	Performance: ssj_ops	Power: Average Active Power (W)	Performance to Power Ratio
100%	98.5%	141,739	353	402
90%	90.0%	129,541	346	374
80%	79.8%	114,893	335	343
70%	69.9%	100,585	324	311
60%	59.7%	85,907	311	276
50%	50.4%	72,541	298	243
40%	39.4%	56,623	283	200
30%	30.1%	43,382	268	162
20%	20.1%	28,946	252	115
10%	9.9%	14,206	233	61.0
	Active Idle	0	213	0
			∑ssj_ops / ∑power =	**245**



Sample of an not energy efficient machine

Application Layer
Power Drainage on Software Resource Utilization

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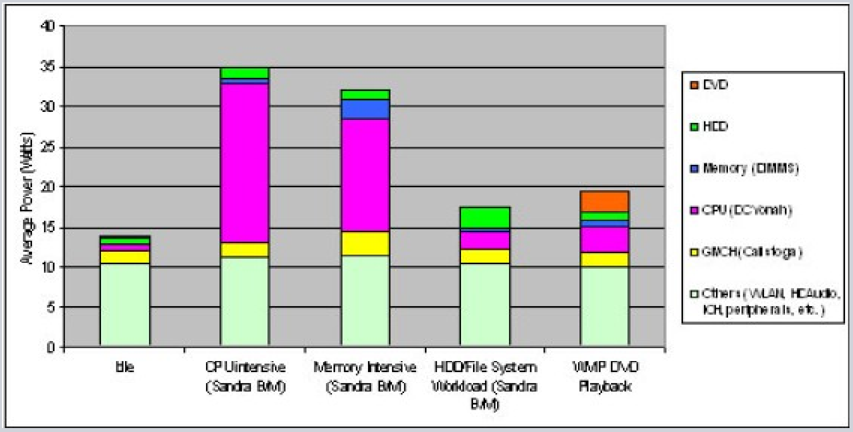

- Utilizing CPU efficiently provides a lot of energy savings potential
- There's a lot of improvement potential for hardware to reduce the idle power consumption

Application Layer
Invest in Performance Optimization

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- **Less work requires less energy**
  - algorithmic transformation (minimum of work)
  - compiler optimization (processor based optimizations, static type checking)
  - check for optimized runtime code vs. interpreted code

- **Program event-based where possible**
  - avoid polling, spin waiting, any regular, periodic flushes to disk or flushing of registry keys (e.g. auto-save, index only if really required)

- **Program multi-core aware, but avoid processor affinity programming**
  - investment in future increasing number of cores
  - upcoming core parking power management

- **Do not use high-resolution periodic timers**

- **Utilize profiler to identify energy hotspots** (energy consumption profiler for consumer PC software still missing)

Application Layer

Demo: Energy Consumption of Event Waiting vs. Spin Waiting

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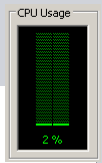
… demonstrated using a very simple C# sample:

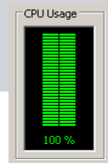
Event Waiting leads to allows CPU idle.




```
//Main Thread
while (true)
{
 ready.WaitOne(); //  Wait until
                  // worker  is ready
    ….            // set work
 go.Set();        // start worker
}

// Worker
while (true)
{
  ready.Set();  //Indicate that ready
  go.WaitOne(); // wait to be kicked
                //off...
 do work
}
```

Spin Waiting leads to full CPU load and energy consumption.




```
//Main Thread
while (true)
{
 while (!readyFlag) Thread.Sleep(0) ;
 readyFlag = false;  // Wait for worker
   …                 // set work
   goFlag = true;   //  Start Worker
}

// Worker
while (true)
{
 readyFlag = true;   //Indicate that
                     //ready
  while (!goFlag) Thread.Sleep(0); ;
                    // wait to be kicked
                    //off...
   … do work
}
```


Application Layer

Use Power Management API

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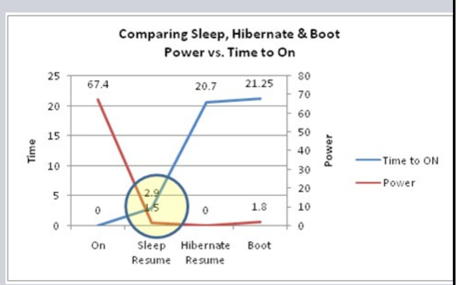
- **Respond to common power management events**
  - Do not depend on blocking a sleep state transition
  - provide code for suspend and resume



- Don't render graphics when display is off
  3D graphics and moving visuals use large amounts of energy

- Scheduling frequent periodic timers
  to poll for work or hardware

- Use only required resources,
  unload plug-ins if not ready to worked

- Adapt, depending on power policies
  - e.g. reduce image resolution, data rate, switch off minor components

- E.g. Windows Messages:
  - Use PeekMessage loop for as little time as possible, PeekMessage prevents processor idle states
  - Use WaitMessage when not background processing

Operating Layer
Minimum Power Management APIs (e.g. Windows XP)

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Event Sources:

PowerModeChanged:
- Suspend or Resume
- and Powermode

poll

Power Management Info:

after receiving a PowerModeChanged event, event information can be gathered by polling Powermode, Information:

```
BatteryStatus:
  - BatteryFlag (High, Low,
    Critical, Charging,
    NoSystemBattery)
- BatteryLifePercent
```

Power Management Manipulation:

```
EXECUTION_STATE:
 - ES_SYSTEM_REQUIRED
 - ES_DISPLAY_REQUIRED
 - ES_USER_PRESENT
 - ES_CONTINUOUS

 SetExecutionState (EXECUTION_STATE)
```

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Application Layer
Minimum Power Management APIs e.g. Windows Vista

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Available Power Notifications:

register

```
hPowerSrc ...     AC/DC, suspend, ...
hBattCapacity ...battery level in percent
hMonitorOn ...    monitor powered up or down
hPowerScheme ... Automatic,HighPerformance,
                  PowerSaver,
```

Asynchronous Notification:
WM_POWERBROADCAST:

PBT_APMSUSPEND:
"System is suspending operation "

PBT_APMSTANDBY:
"System is standing by "

PBT_APMRESUMECRITICAL:
"Resuming after critical suspension."

PBT_APMRESUMESUSPEND:
"Operation resuming after suspension."

PBT_APMRESUMESTANDBY:
"Operation resuming after stand by."

PBT_APMBATTERYLOW:
"Battery power is low."

PBT_APMPOWERSTATUSCHANGE:
"Power status has changed."

PBT_APMOEMEVENT:
"OEM-defined event occurred.";

PBT_APMRESUMEAUTOMATIC:
"Resuming automatically after event."
.....

Power Management Manipulation:

```
EXECUTION_STATE:
 - ES_SYSTEM_REQUIRED
 - ES_DISPLAY_REQUIRED
 - //ES_USER_PRESENT (only for legacy)
 - ES_CONTINUOUS

SetThreadExecutionState (EXECUTION_STATE)
```

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Application Layer
Summary Energy Efficiency Measures

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Layer Specific:

- Event-based Programming
- Implement Power Management APIs
- Parallel and concurrent programming (avoid spin-waiting)
- Compiler optimizations
- Library optimizations (Type Marshaling, static vs. dynamic type checking)
- Power/energy profiling tools
- Energy efficient software design patterns

Cross-Layer:

- Energy efficient software domain patterns
- Provide information for system management tools to support overall optimization

Software Engineering
Integrate Energy Efficiency in all Development Phases

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Requirement Engineering	Check integration of dynamic power management requirements and platform requirements. Specify according requirements, also for test.
System Design & Software Architecture	Choose platforms with power management capabilities. Incorporate power management application and test interfaces to system components. Choose development environment supporting energy profiling. Design for an event driven architecture.
Implementation	Implement power management interfaces and monitoring interfaces. Use method profiling to find out energy consumption hotspots in libraries and own source code (processor cycles). Define “energy budgets” for methods.
Test	Integrate unit tests to profile „energy budget“ for method tests. Integrate test tools for testing system suspend/resume and application scaling
Improvement Loop (Feedback)	Integrate power/energy management/ monitoring and reporting to allow improvement on changing in the field.

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Key Takeaways and Issues

- IT energy consumption became a major CO_2 contributor
- Today's CIO's and IT management processes are not aware of high energy consumption and need to be refined
- **Improve energy efficiency on every architecture layer**
  - choose energy efficient hardware
  - utilize hardware virtualization
  - implement dynamic OS power management
  - program event-based, less code requires less energy
  - consider middleware energy consumption in your overall system architecture

Start today to integrate energy efficient software development to your software engineering process!
Plan a single work package only for energy efficiency!

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Data Center Energy Efficiency is an important Part of the Siemens Green IT Strategy

Challenge

- Lack of transparency in energy consumption
- Dramatic increase of increase of capacity
- Lack of expertise in market
- Power cost increasing

Benefits

- Server consolidation ratio of 15 to 1 which equals energy efficiency increase of 83%
- File storage server reduction by 91%
- Capacity utilization rate of 80% for a storage server (referring to an initial value of 30%)
- Usage of ground water for air cooling leads to energy savings of 50% compared to conventional chiller

Solution

Siemens Data Center Beijing

- Tier-2 regional site comprising 100 racks, 630 servers and 490m² of floor space.
- Green by design and operation
- Environmental construction
- Free air-based cooling
- Energy-saving lighting


Siemens has built up the Relevant Competencies to Address Environmental Sustainability
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Fossil Power Generation
Renewable Power Generation
Power Transmission
Power Distribution
Environmental Technologies
Healthcare
IT Solutions and Services
Mobility
Solutions for Industry
Lighting (Osram)
Building Technologies
GREENBUILDING
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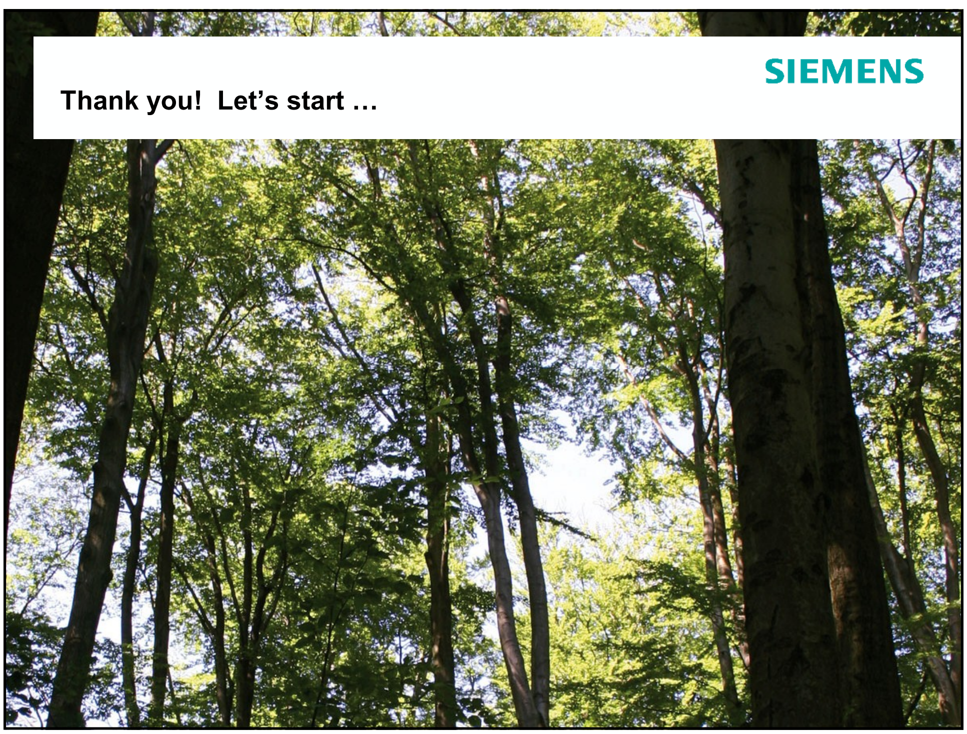
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Thank you! Let’s start …

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References

c't 4,2008 magazine: Energy costs Germany 20 Cent/kWh, Germany energy mix: 616g CO2/kWh
VW Golf Diesel/ 90hp/ 5.1l per 100km (0.5018kWh/km)/ 135g CO2/km / 9.84kWh per liter

MMS 2008 - Las Vegas "How System Center helps with your Green IT Initiatives ", Frank Koch, 2008

Energy Star® http://www.eu-energystar.org/en/en_007c.shtml

Processor Power Management in Windows Vista and Windows Server 2008
http://www.microsoft.com/whdc/system/pnppwr/powermgmt/ProcPowerMgmt.mspx

How to Enable Processor Power Management in Windows Server 2003
http://www.microsoft.com/whdc/system/pnppwr/powermgmt/w2k3_ProcPower.mspx

Windows Vista Energy Conservation
http://www.microsoft.com/whdc/system/pnppwr/powermgmt/VistaEnergyConserv.mspx

Best practices for datacenters
http://download.microsoft.com/download/a/7/b/a7b72ab1-ca17-4589-923a-83b0ff57be6d/Energy-Efficiency-Best-Practices-in-Microsoft-Data-Center-Operations-CeBIT.doc

The Green Grid organization
http://www.thegreengrid.org

PhD Thesis "Adaptive Power Aware Remote Processing, Gerald Kaefer, 2004"
http://www.iti.tugraz.at/en/people/kaefer/publications/phdthesis_kaefer.pdf

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References

Intel 2007: "Creating Energy-Efficient Software", by Bob Steigerwald, Rajshree Chabukswar, Karthik Krishnan, Jun De Vega

Microsoft 2009: "Windows 7 Power Management, Power Management Improvements in Windows 7, beta",

PDC 2005: „Windows Vista: Developing Power-Aware Applications", Pat Stemen, Geralyn Miller

IBM 2006: "Trends in der ITK", Antonio Palacin, IBM SAP International Competence Center

Power / Energy Taxonomy

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Joule …	the international standard unit of energy measurement [1 Joule = 1 Ws]
Energy …	„capacity to work“, for this talk, the term means the amount of joules required to carry out a specific task. E.g. the energy required to lift a 0.1kg object 1 meter against the pull of earth‘s gravity is about 1 Joule
Power ...	the amount energy consumed per unit of time, typically measured in Watts, 1 Watt equals 1 Joule per second.
Heat (energy)…	the form of energy dissipated by electronic equipment during operation.
Electric Energy costs …	Germany 20 Cent/ kWh
Germany energy mix …	0.616kg CO_2/ kWh
CO_2 car reference...	VW Golf Diesel (90hp/ 5.1l per 100km)with 0.5018kWh/ km; 135g CO_2/ km; 9.84kWh/ liter