Institute for
Information Technology

Energy Efficiency in ICT

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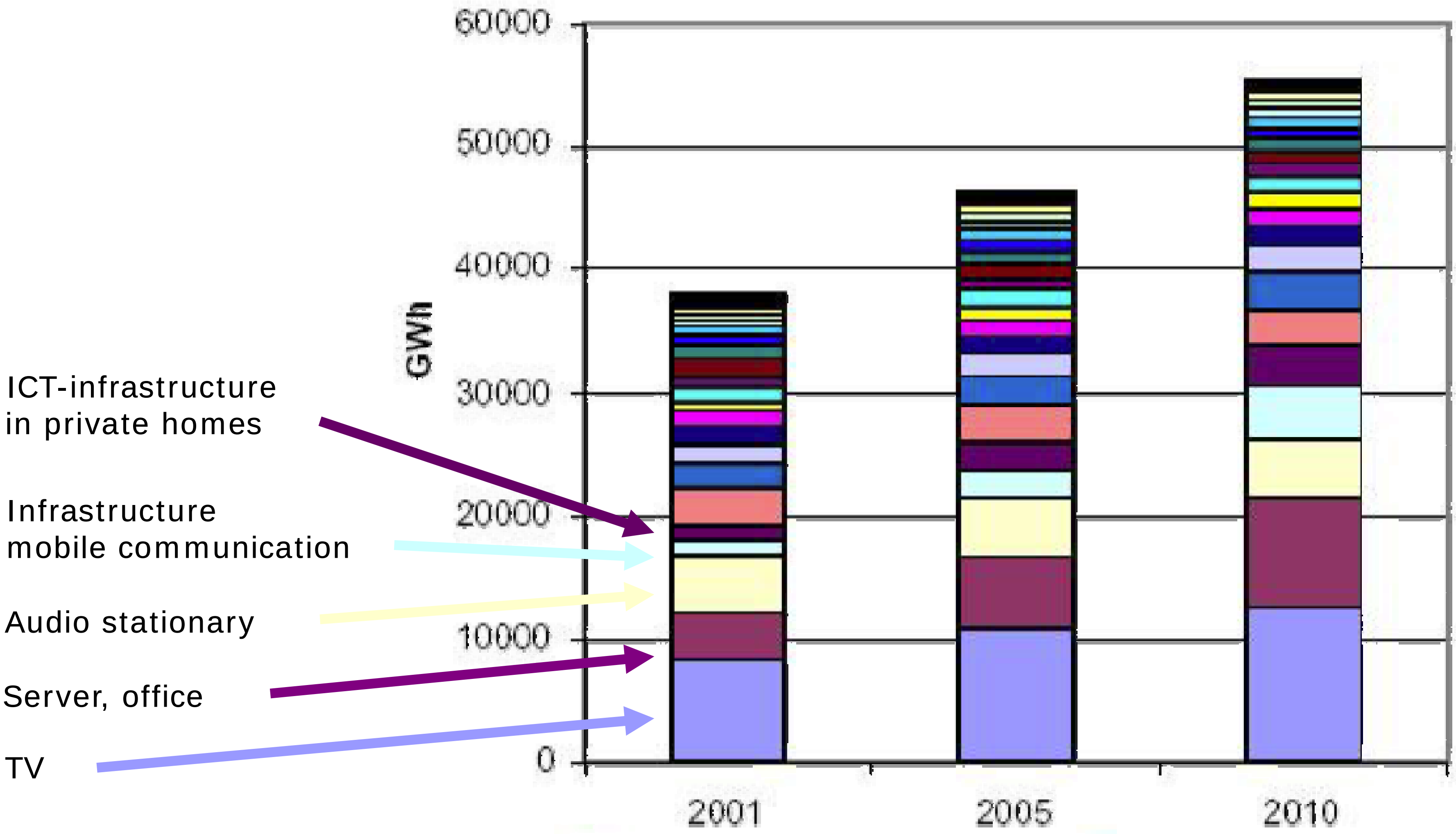
Energy Consumption, Climate Protection, Costs

- **Power Consumption of ICT (End Devices and Infrastructure) in Germany**
  (Source: Cremer et al. 2003)
  - 2001: 38 TWh (8% of power consumption)
  - Compared to 10.7 TWh generated from wind energy
    (Source: Bundesverband Windenergie)
  - 2010: 55 TWh (11% of power consumption)
- **CO_2-Emissions 2004 in Germany**
  - ICT: 28 Mio. t CO_2 (due to power consumption)
  - Compared to complete aircraft traffic of 22 Mio. t CO_2
- **Increase especially in ICT-Infrastructure (UMTS-Network, Servers, Routers etc.)**
  - The highest electricity consumers are data centers
  - Servers: 180 TWh in 2005 relate to 18 nuclear power plants worldwide
  - 80% of all servers are located in data centers

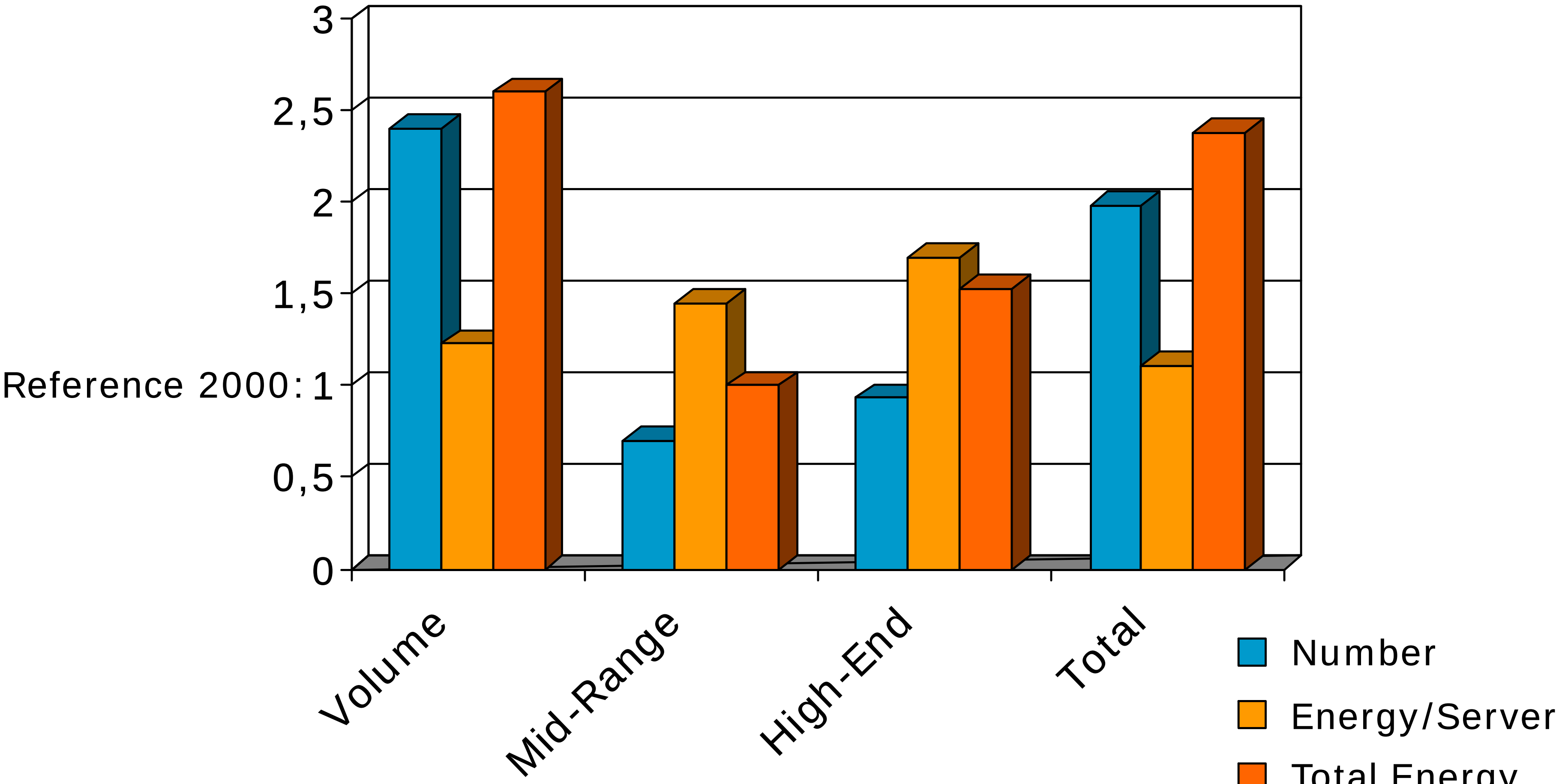
- **Increase of Operating Expenses due to Energy Costs**
  - Energy costs worldwide for servers in 2008: approx. 40 billion US$
  - Soon 50% of operating expenses will be caused by power supply and cooling

Energy Consumption of ICT in Germany



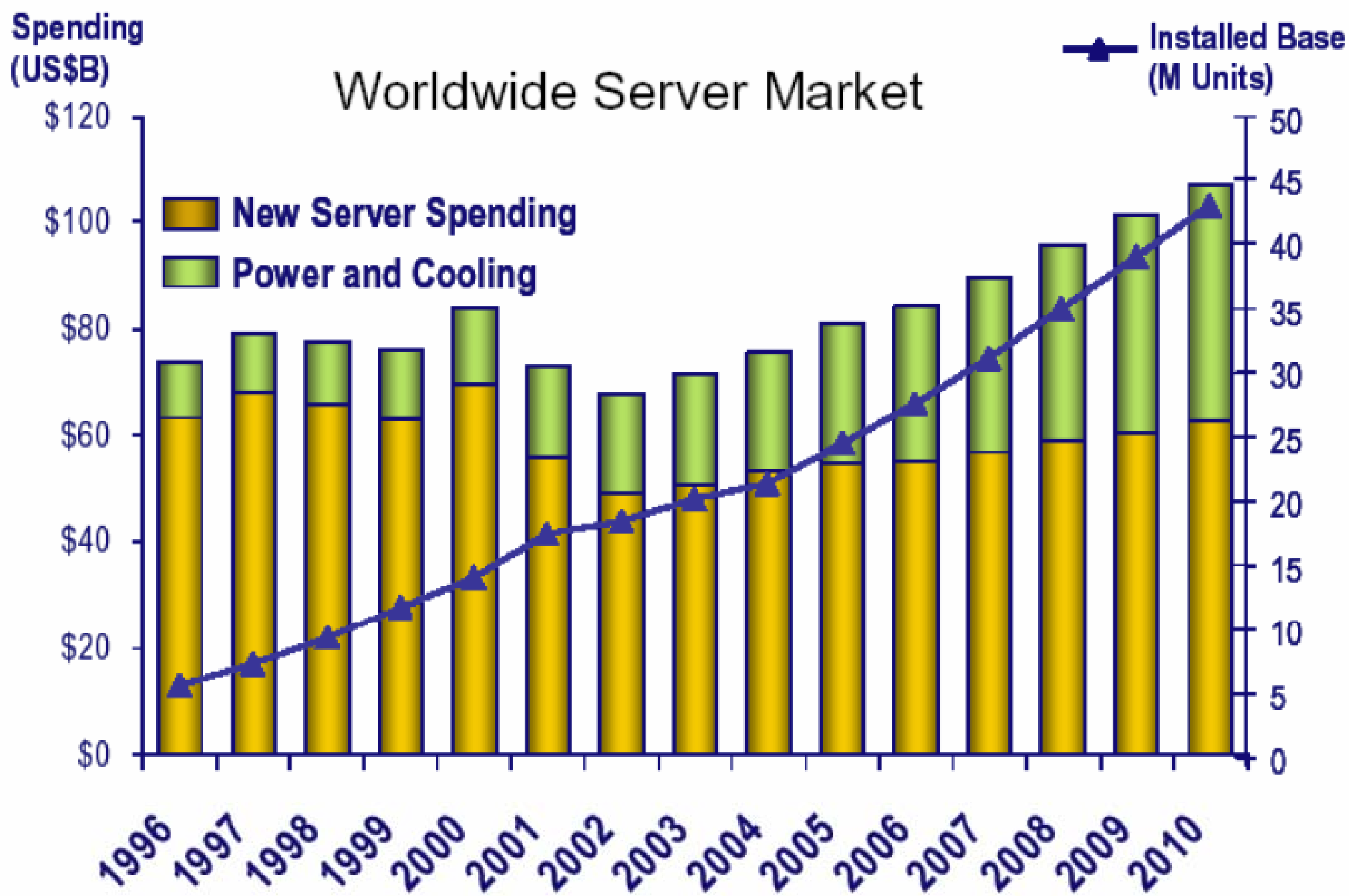
Source: Borderstep 2007/Cremer et. al. 2003

Worldwide Energy Consumption of Servers 2005 vs. 2000



Source: Koomey, 2007

The Economic Consequences



Source: IDC 2006

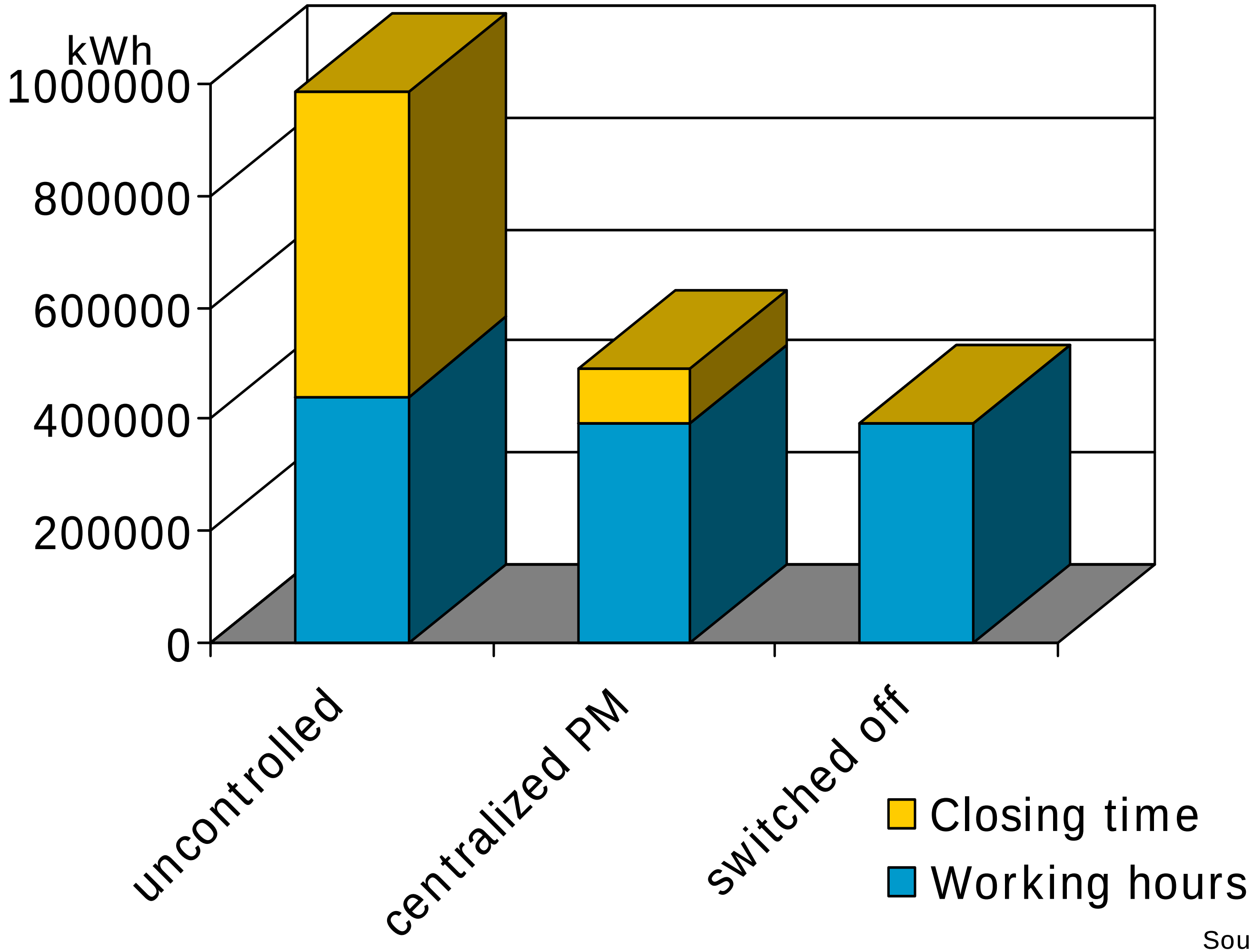
Problem Awareness of Data Center Operators

What is the greatest facility problem with your current data center?	2007	2006
Insufficient cooling	27%	35%
Insufficient raised-floor space	10%	12%
Insufficient power	47%	33%
Poor location	3%	10%
Excessive facility cost	5%	6%
None of the above	8%	4%
Total number of responses	119	125

Source: Gartner (November 2007)

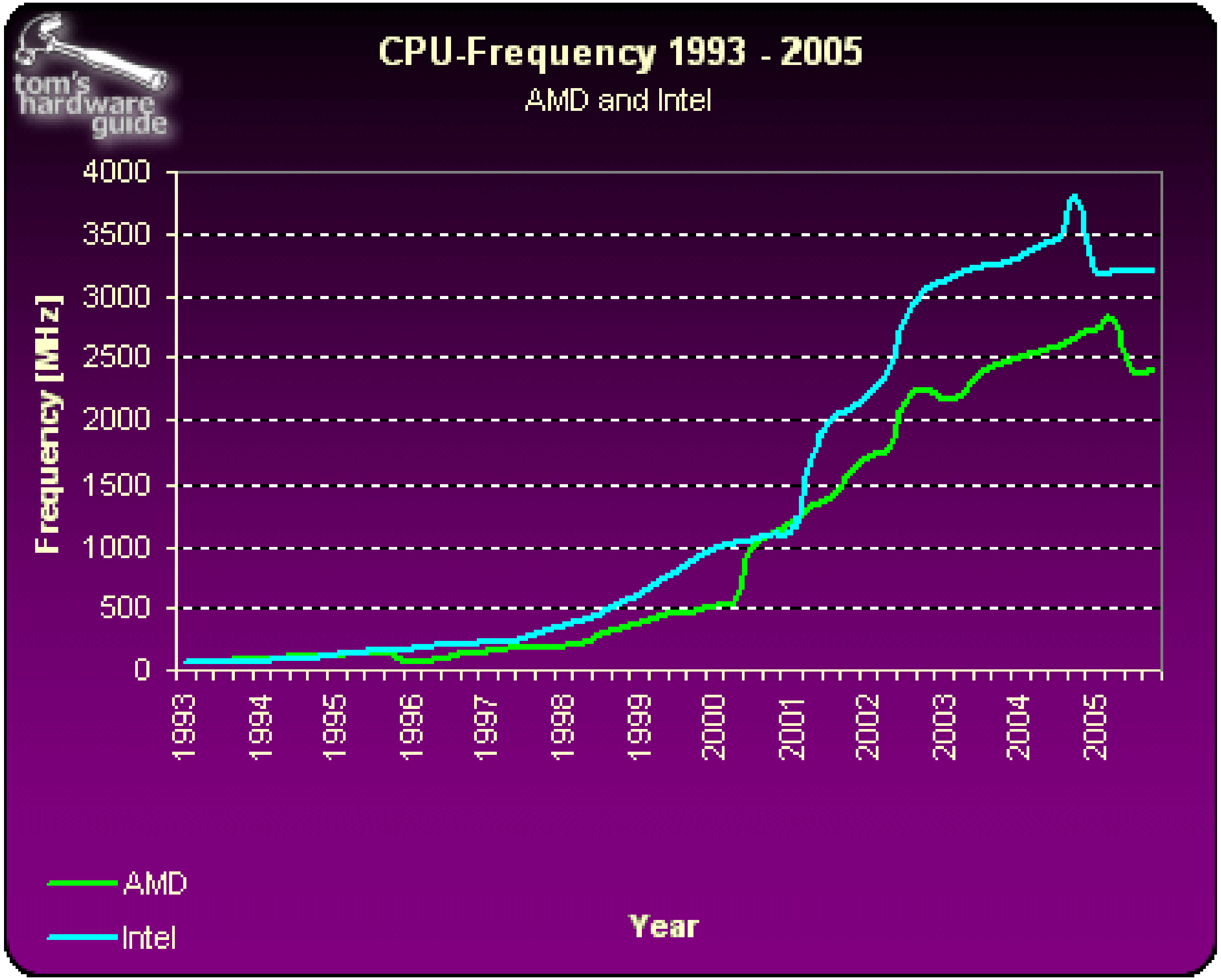
Power supply and cooling together: 74%

Energy Consumption in Enterprises (2,500 PCs)



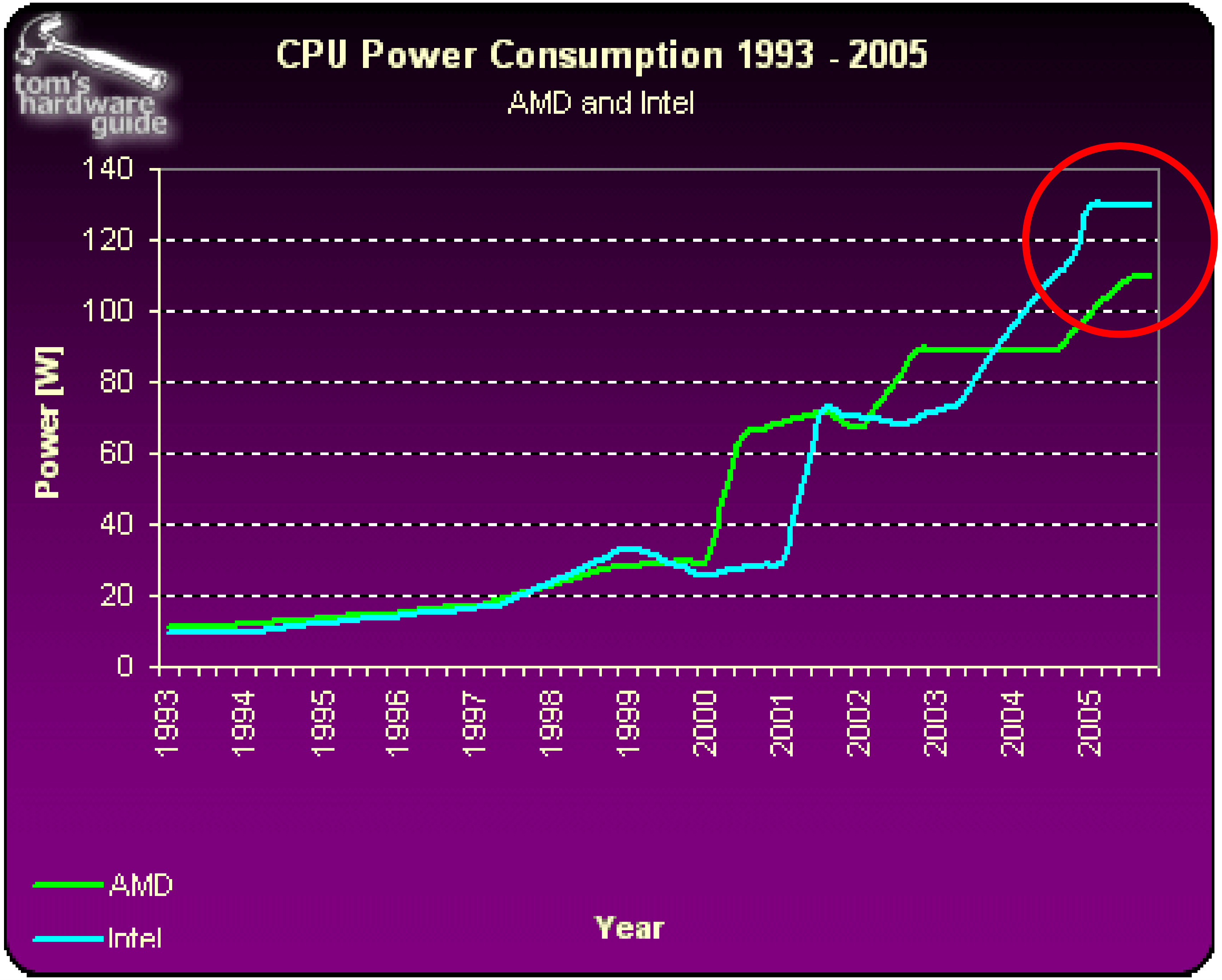
Source: Gartner 2007

Core of the Problem: The Required Computing Performance



Source: tom's hardware guide

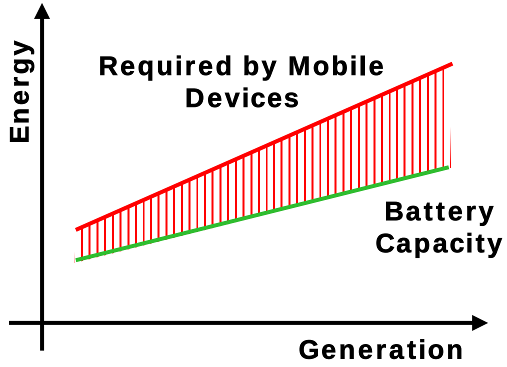
Cause: The Performance Barrier



Source: tom's hardware guide

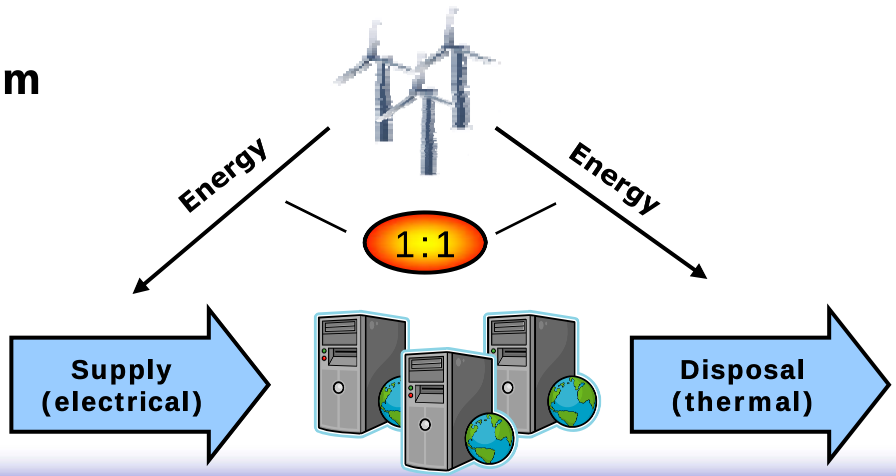
Technical and Economic Challenges

- **Limited Run-Time**
  - Energy demand raises faster than battery capacity
  - Problematic for mobile devices: notebooks, mobile phones, PDAs, ...



- **Added Costs**
  - Typically relevant for devices for private use: desktop PCs, TVs, DVD players, ...
  - Of increasing importance in the commercial domain: e.g. work station PCs

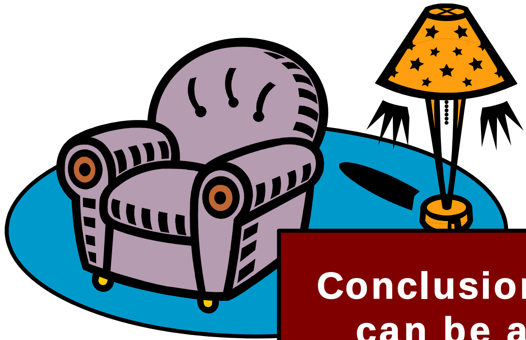
- **Energy Supply and Disposal Problem**
  - Increasingly problematic in data centers
  - Complex air conditioning for energy disposal required
  - Sometimes, even the supply of energy is a problem



Abstract Examination – Energy Efficiency

What is Energy Efficiency?

optimize effectiveness



not efficient — efficient

ulb

Energy Saving Bulb

LED Illuminant

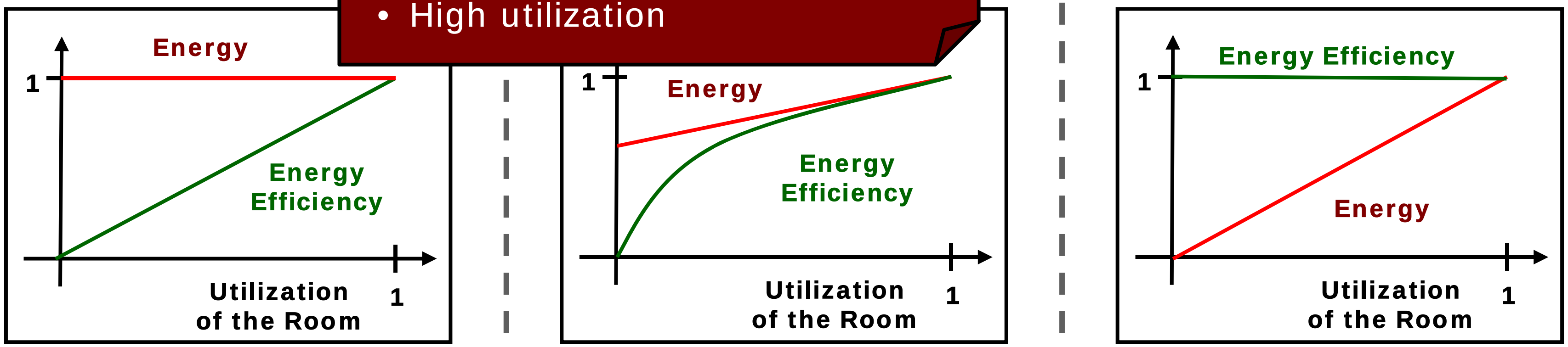
Conclusion: Energy efficiency can be achieved by:

- Optimized effectiveness
- Energy consumption proportional to usage
- High utilization

energy consumption proportional to usage

always on

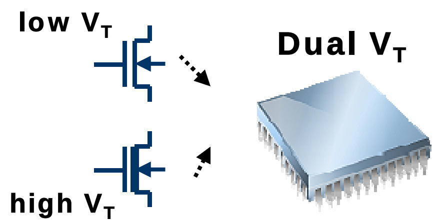
light off, if room not used



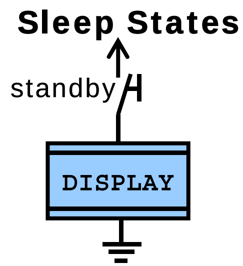
efficient only at high utilization — always efficient

Practical Implementation – Energy Efficiency in Mobile Phones

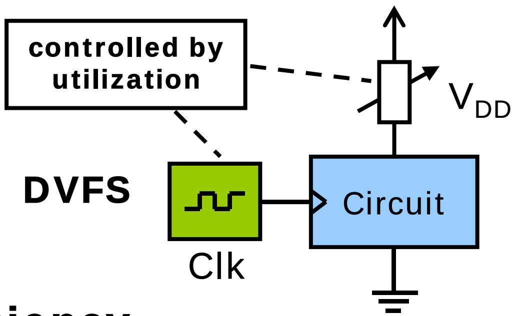
- **Optimize Effectiveness**
  - Adoption of low-power technologies and design solutions in chip development
  - **Objective:** minimizing steady-state power dissipation



- **Raising Utilization**
  - By means of load alignment



- **Energy Consumption Proportional to Usage**
  - Sophisticated power management
    - Disabling unused circuits
    - Reducing performance during phases of lower utilization
  - **Objective:** Customizing the energy consumption according to the respective usage scenario



- **Conclusion: Due to technical problems, vigorous usage of techniques to raise energy efficiency**

Practical Implementation – Energy Efficiency in PCs 1/3

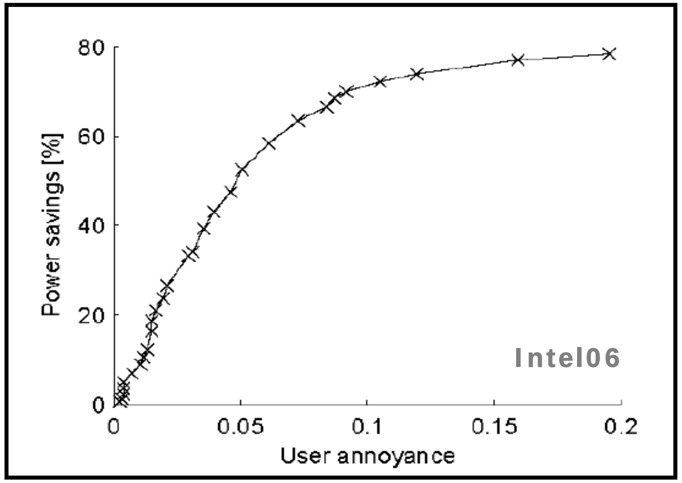
- **Optimize Effectiveness**
  - Technically feasible: low power CPU, low power graphics card, 80% mains supply, thus no need for a fan
  - Today, instead of energy consumption rather performance and pricing are important purchase criteria
  - Only secondary effects (fan noise, high temperatures and short battery life time in notebooks) are reasons to purchase energy efficient systems

- **Raising Utilization**
  - Matching of the resources
    - „sending emails“ and „surfing“ needs **no** high-end PC
  - Matching of the load
    - temporally - spatially

- **Energy Consumption Proportional to Usage**
  - Technically feasible:
    - Shut down of individual components (hard disc, display, ...) possible
    - Low power consumption during standby state
  - Controlled by software with a timeout-based power management

Practical Implementation – Energy Efficiency in PCs 2/3

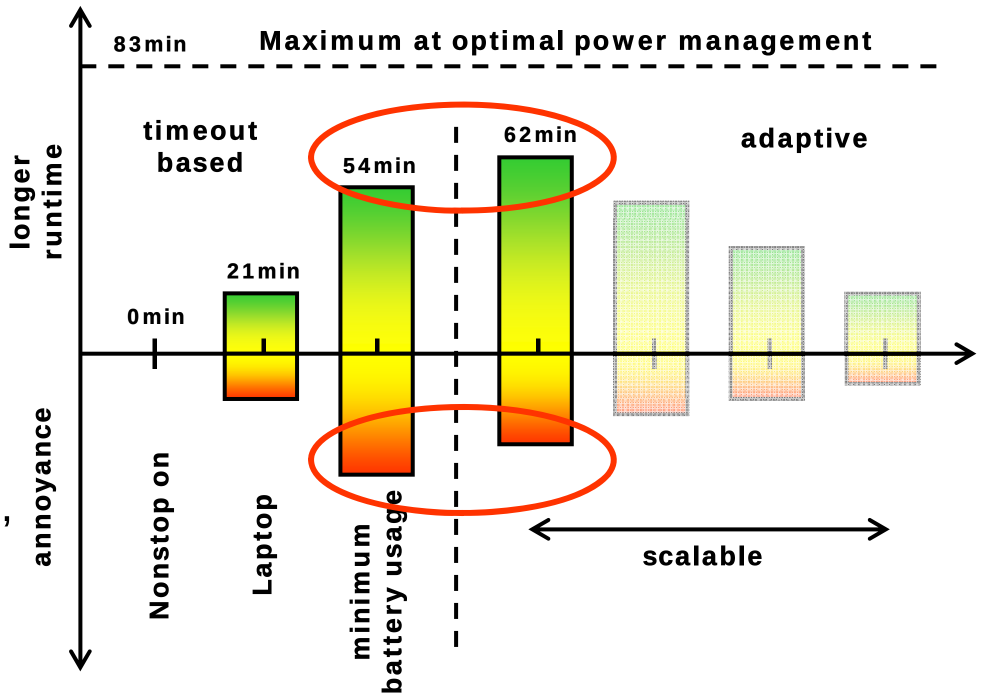
- **Problems of the Present Timeout Based Power Managements**
  - Idea: After some idle-time, the user is considered to be absent -> turn off device (e.g. display)
  - Error-prone (e.g. while user reads)
  - The chosen balance between saving energy and annoyance often is to the disadvantage of energy saving



- **Solution: Intelligent Power Management**
  - Idea: Adapt the power management to the pattern of use
  - For the first time, basic research was included in a product

Practical Implementation – Energy Efficiency in PCs 3/3

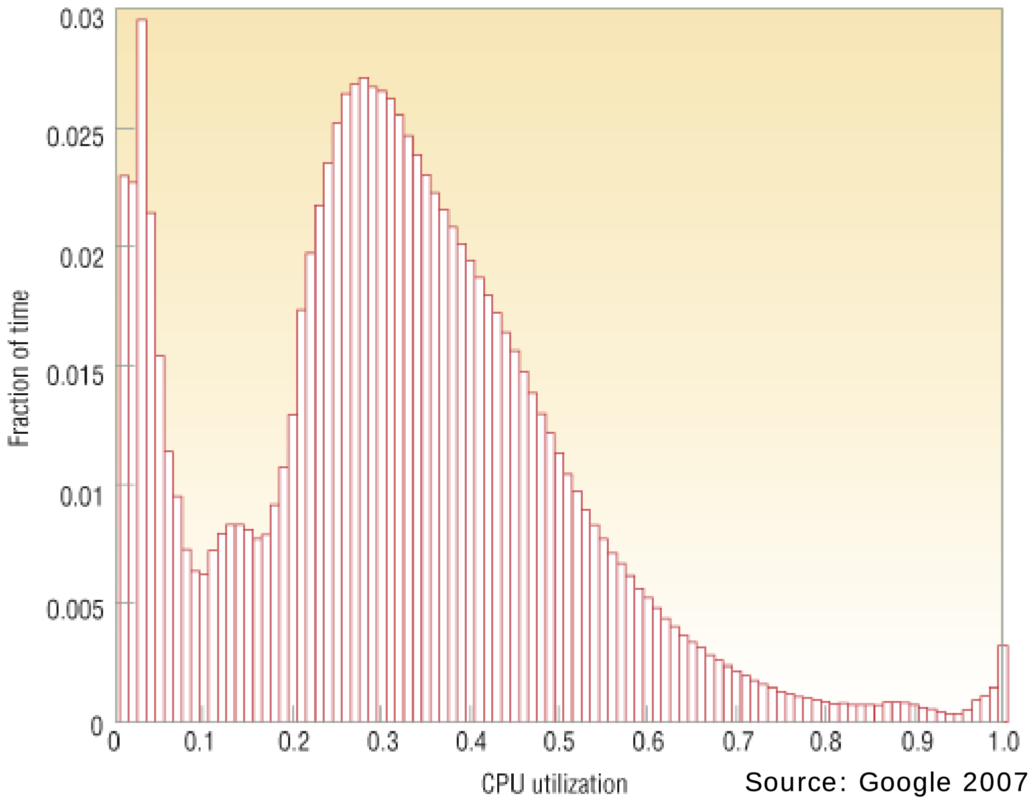
- **Comparing Results of Adaptive vs. Timeout Based Power Management**
  - Use case: “Work of a traveling salesman”
  - Runtime of the notebook without PM: 5h
  - Due to breaks (phone call, reading of papers, …) max. extra time: 83min
  - “adaptive” more energy efficient, with less false shut downs



- **Conclusion:**
  - Energy efficiency is often a question of “financial sweeteners”
  - Technical possibilities are available; but until now not sufficiently used

Practical Implementation – Energy Efficiency in Data Centers 1/3

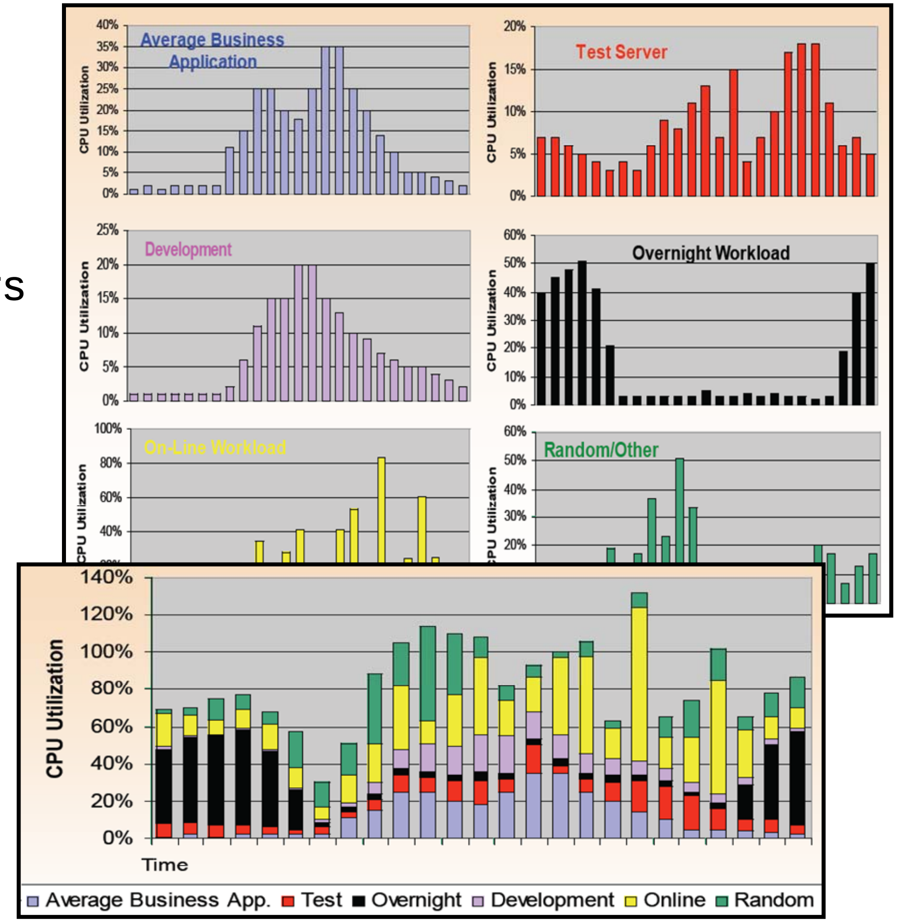
- **Effectiveness**
  - Energy efficiency only if neutral to performance
    - Mains supply with high effectiveness (e.g. in Blade servers)
  - Smaller improvements are possible, but one cannot expect major advancements in the near future
- **Optimize Utilization**
  - Average utilization of today's servers (measured approx. 5,000 servers over a 6 month period)



Source: Google 2007

Practical Implementation – Energy Efficiency in Data Centers 2/3

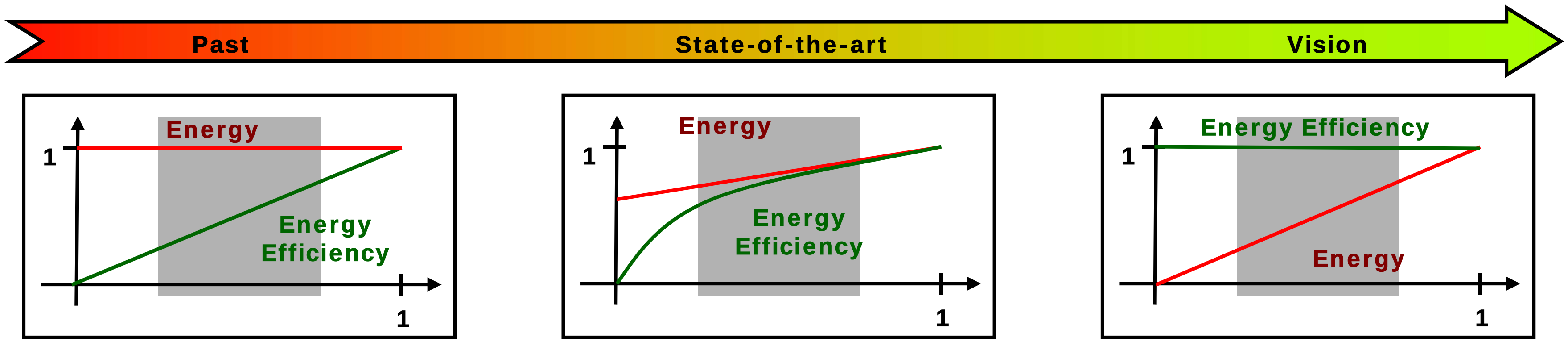
- **Optimize Utilization**
  - Additional strong dependency on time and type of server
  - Optimization by consolidation
    - Implementation of several servers on one hardware resource
  - Realization by virtualization
    - several virtual operating systems are independently executed on one single host system



Source: Vossel Solutions

Practical Implementation – Energy Efficiency in Data Centers 3/3

- **Energy Consumption Proportional to Usage**



- **Server without power management**
- **Constant consumption**
- **Energy efficiency only depending on utilization**

- **Power management in modern CPUs result in a minor utilization dependant consumption**
- **in Blade servers load dependant control of mains supply**

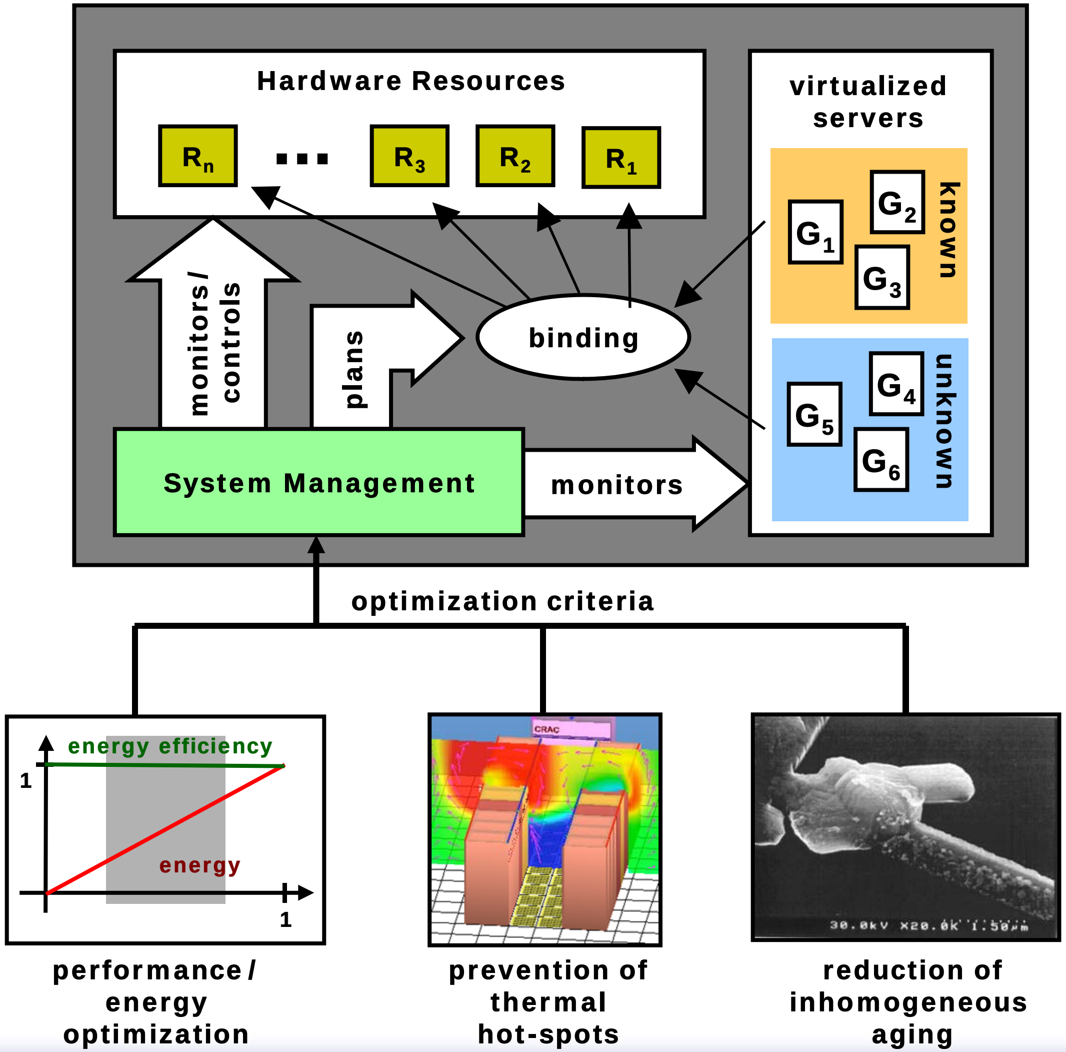
- **Complete usage dependant energy consumption**
- **Realizable by global power management in the entire data center**

Research Project at OFFIS

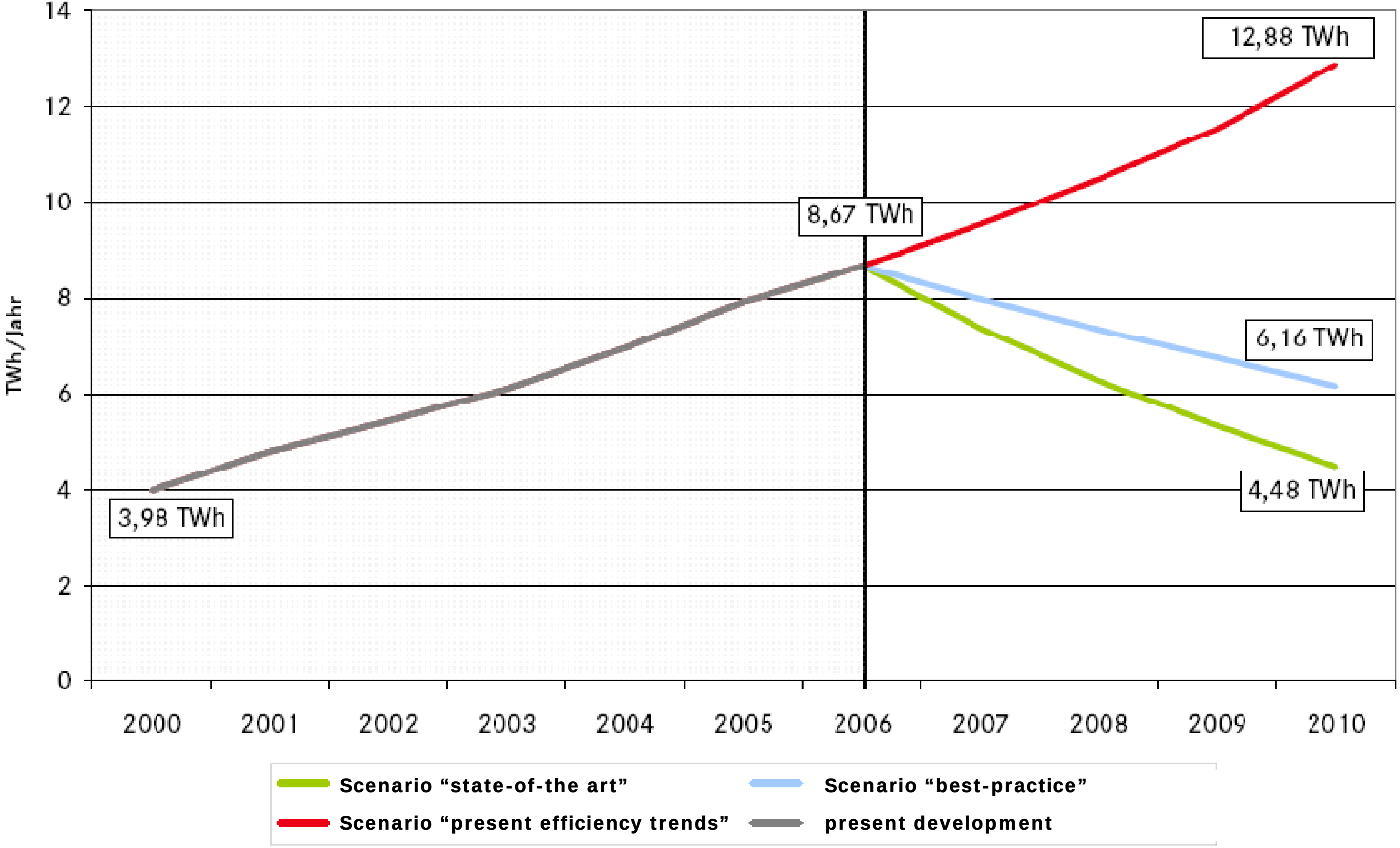
- **Conclusion**
  - Raising the load by consolidation
  - Nearly complete usage-proportional energy consumption is reachable with system wide power management
    - Without penalty on performance
    - With higher availability

Practical Implementation – Possibilities by System Management

- **Virtualized Data Center**
  - Regarding their behavior, known and unknown virtualized servers
- **System Management**
  - monitors virtualized servers
  - monitors and controls the hardware resources
  - plans binding
- **Optimization Criteria**
  - Energy/Performance
  - thermal behavior
  - homogeneous aging

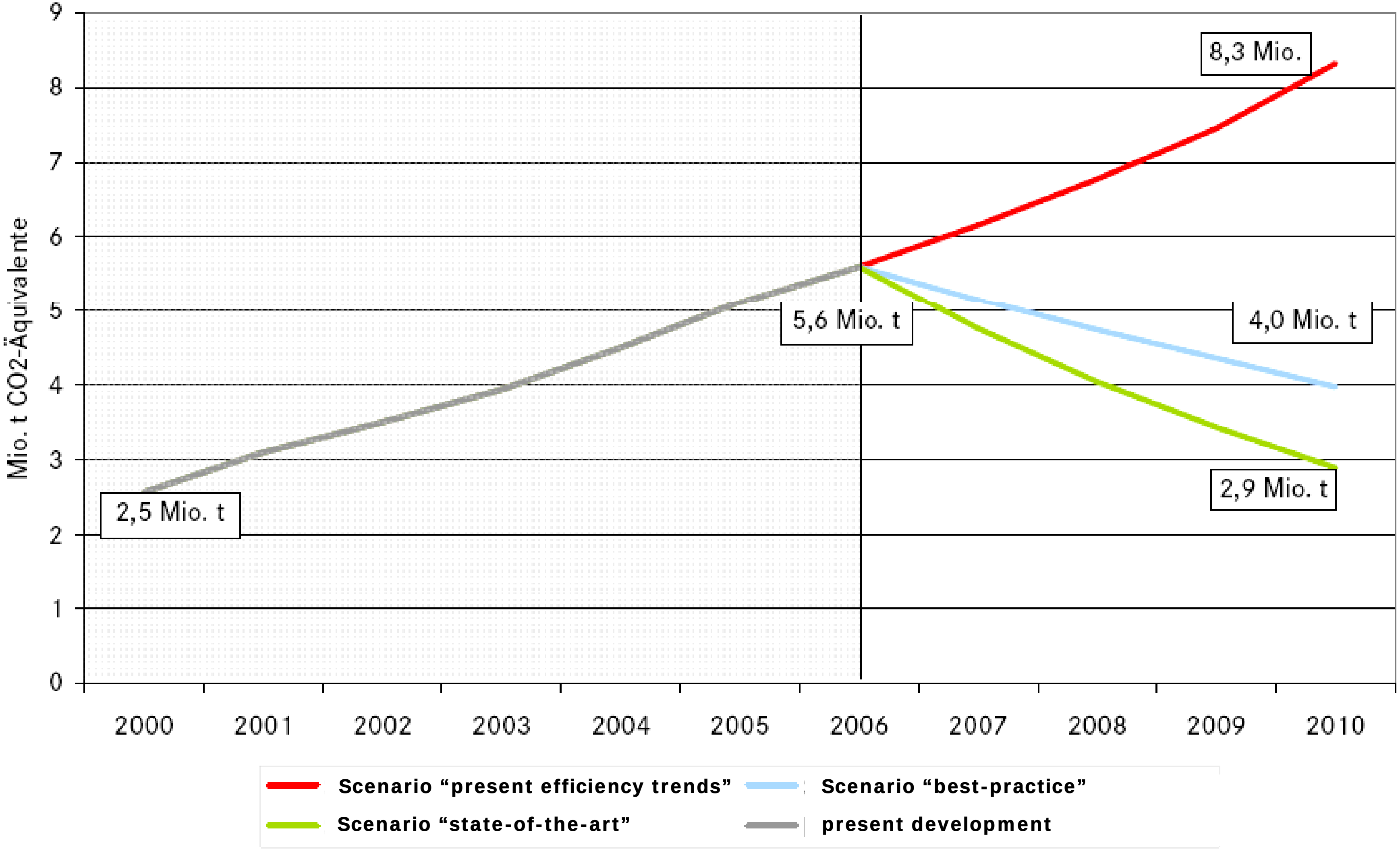


Power Consumption of German Data Centers



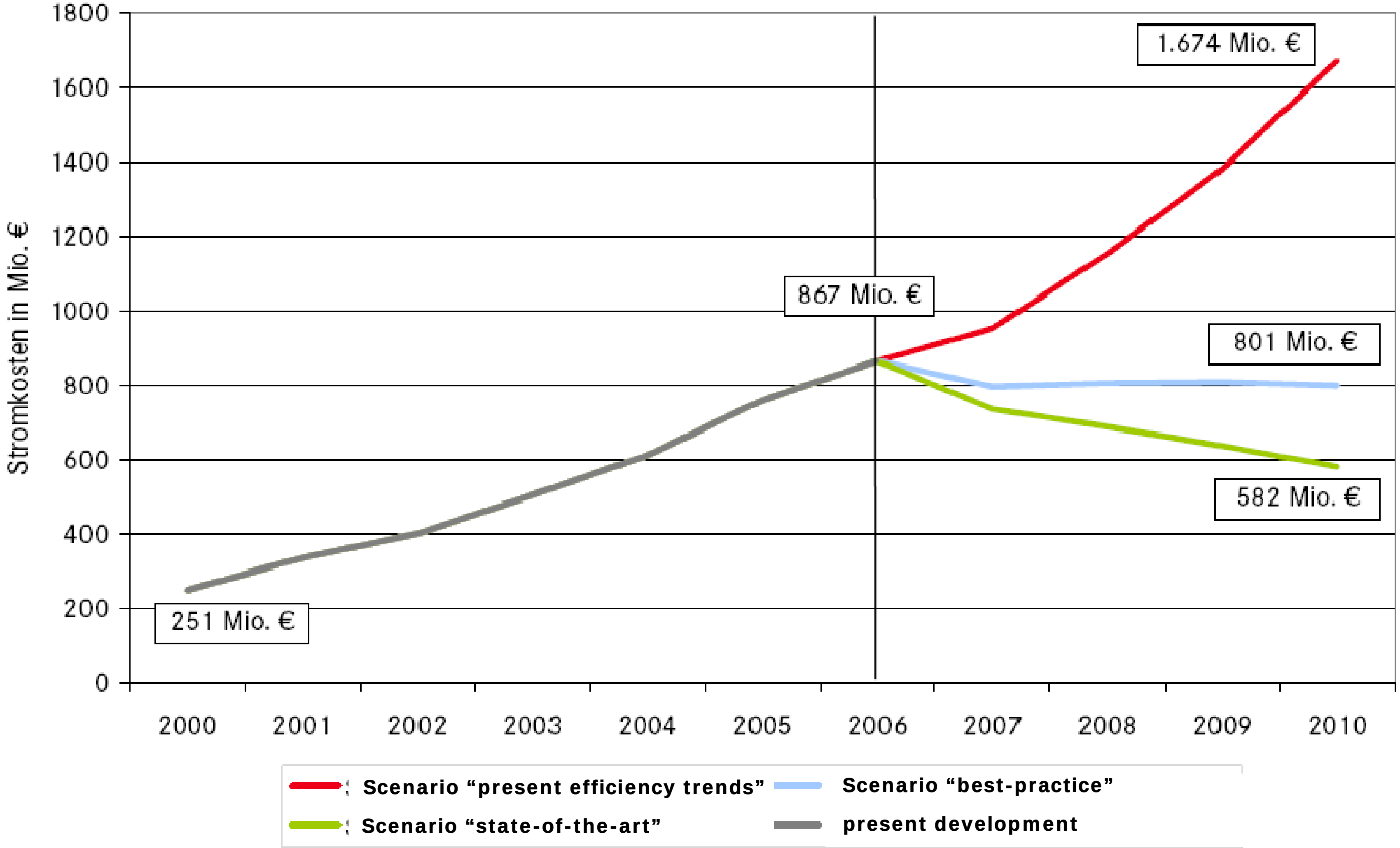
Source: Borderstep 2007

CO_2 Emissions of German Data Centers



Source: Borderstep 2007

Energy Costs of German Data Centers



Source: Borderstep 2007

Practical Implementation – Example Projects

- **Strato's CO_2-free Data Center**
  - Increased energy efficiency
    - Low power CPUs, optimized software (Sun Solaris 10) optimized building services and air conditioning
  - Energy supply by water power

- **The "green" Data Center of Host Europe**
  - Highly available and energy efficient,
  - Raised effectiveness of the supply components, cooling with outside air, ...,
  - 30% lesser energy consumption

- **Bio-Gas Fuel Cell in T-Systems RZ-Munich**
  - "Our servers devour green stuff"
  - 250 kW of altogether 10 MW

Finally ...

- **Google 2005**
  - 1 cluster = 31,654 servers
  - served 40 Mio. requests/day
  - costs about 300 MWh/day
  - one request costs about 8 Wh

- **Second Life 2007**
  - approx. 2000 servers
  - 36,000 players simultaneously
  - one avatar costs about 195 kWh/year or 129 kg CO_2

  - Compare: a human exhales about 250 – 400 kg CO_2

- **Thanks to Rolf Kersten: http://blogs.sun.com/rolfk/**

Conclusion

- **Technical problems already force manufacturers of mobile devices to implement radical new concepts.**
- **Increasing technical, economic and environmental interest in energy efficiency in data centers and ICT-infrastructures:**
  - Potential and first technical alternatives are already available.
  - Further innovative ideas have to be developed and evaluated.
  - Holistic concepts have to be developed.
  - Savings potential in 2010 more than 8 TWh / 5,4 Mio t CO_2 / 1,1 Mrd. €
- **Very good prerequisites for applying new technologies, since**
  - environmentally and economically reasonable,
  - technically required and feasible.
- **Actions**
  - Raise cost awareness in decision makers
  - “Best practice” information
  - Roadmap to coordinate suppliers towards market launch
  - Flagship initiatives (improving the state-of-the-art)
  - Energy-labels for the consumers market