Whole system redesign for electricity efficiency: Some lessons from the world of cloud computing

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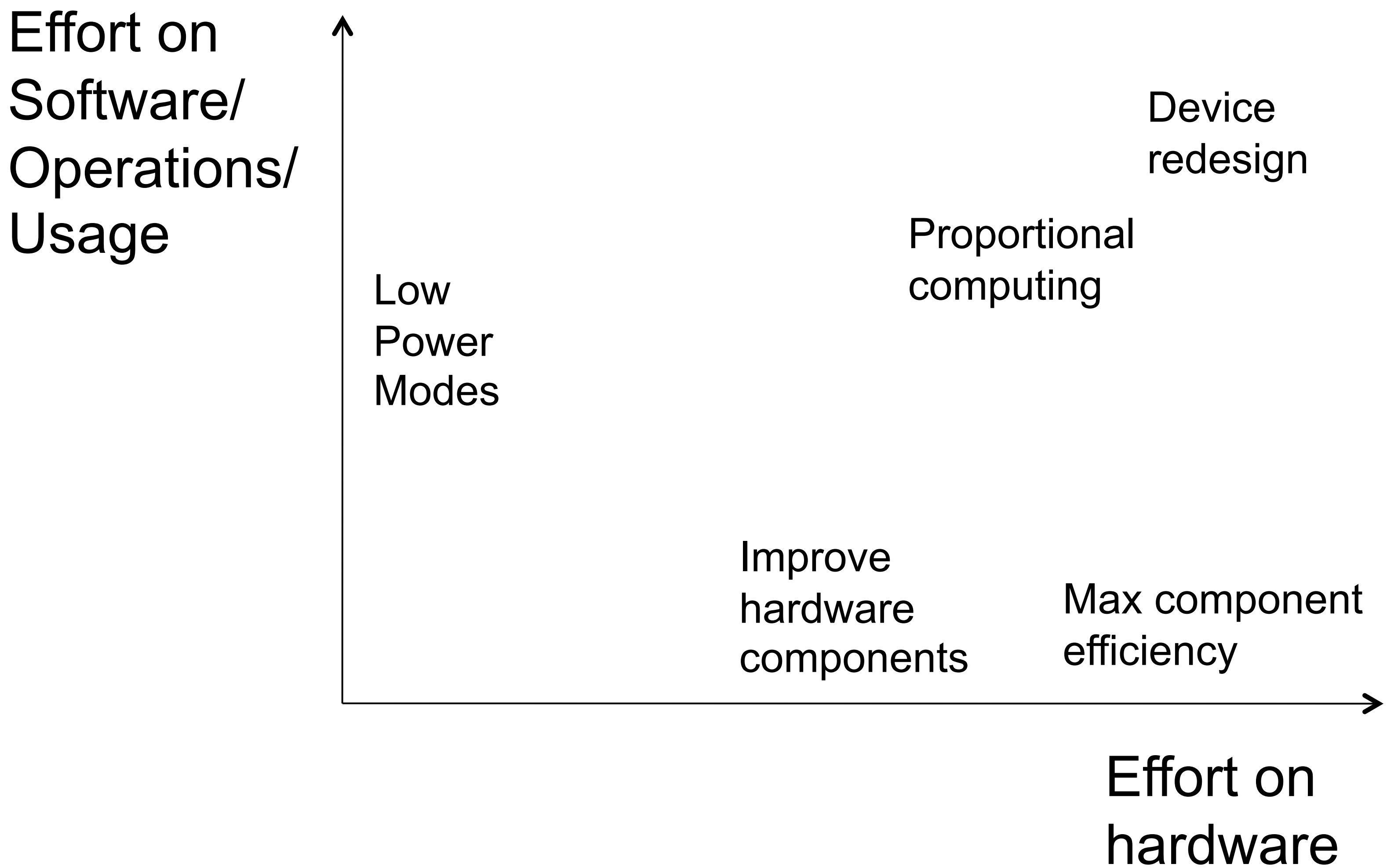
Categories of IT

- End user (stationary and mobile)
  - Desktop PCs and other office equipment
  - Smart phones, PDAs, laptops
- The cloud
  - Networking
  - Data centers
- Embedded systems

Device strategies for efficiency

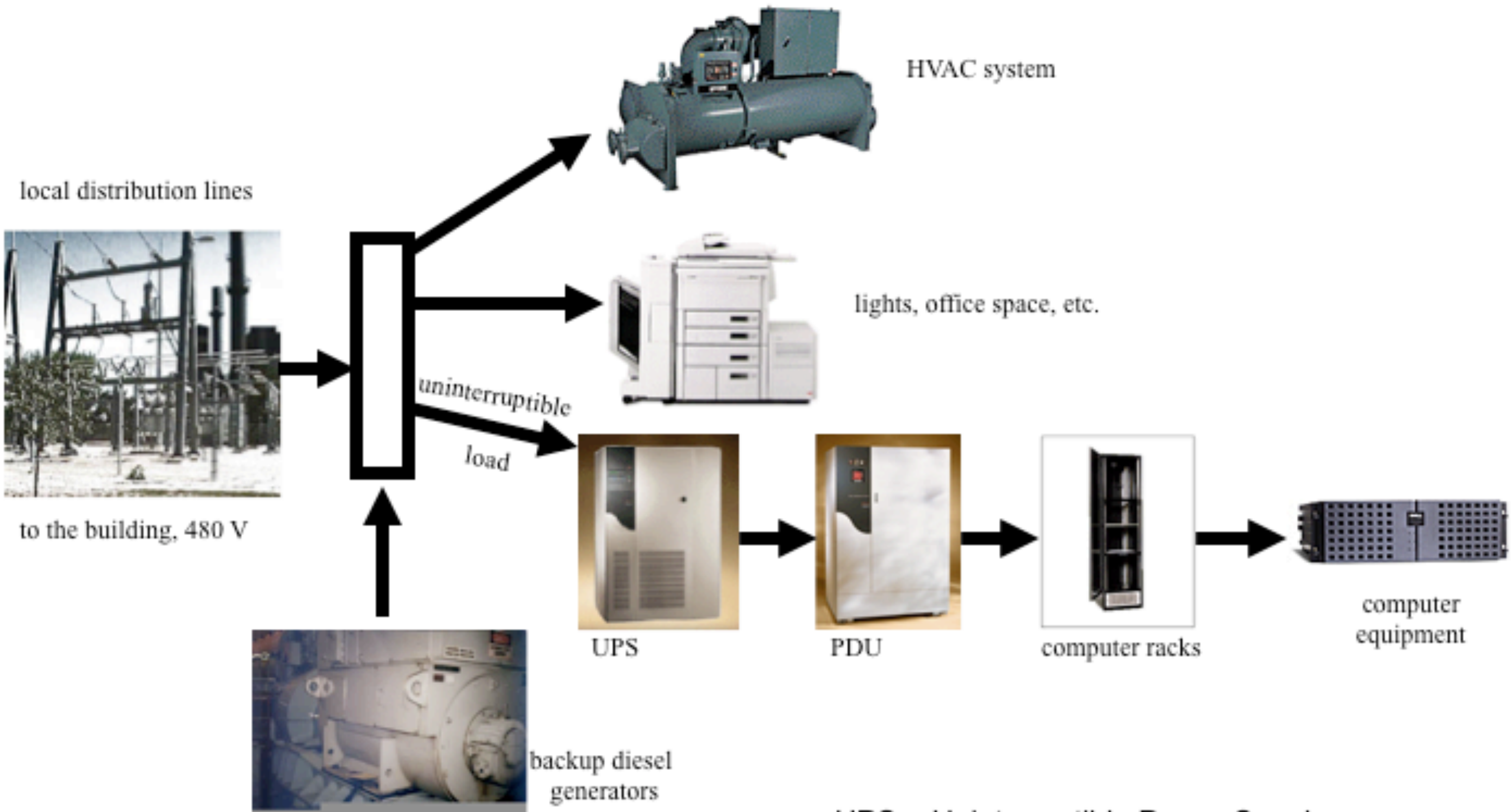


Going beyond device redesign

- Consider the whole system, as per Amory Lovins of Rocky Mountain Institute
  - Think about tasks
  - Redesign devices and systems from scratch, ignoring illusory historical constraints, but heeding real ones
  - Make products superior in many ways (efficiency won't sell by itself)
  - Shift tasks to more efficient parts of the system (stationary to mobile, stationary to the cloud)

Data centers, where the cloud resides, are where the world of bits meets the world of atoms

Electricity Flows in Data Centers

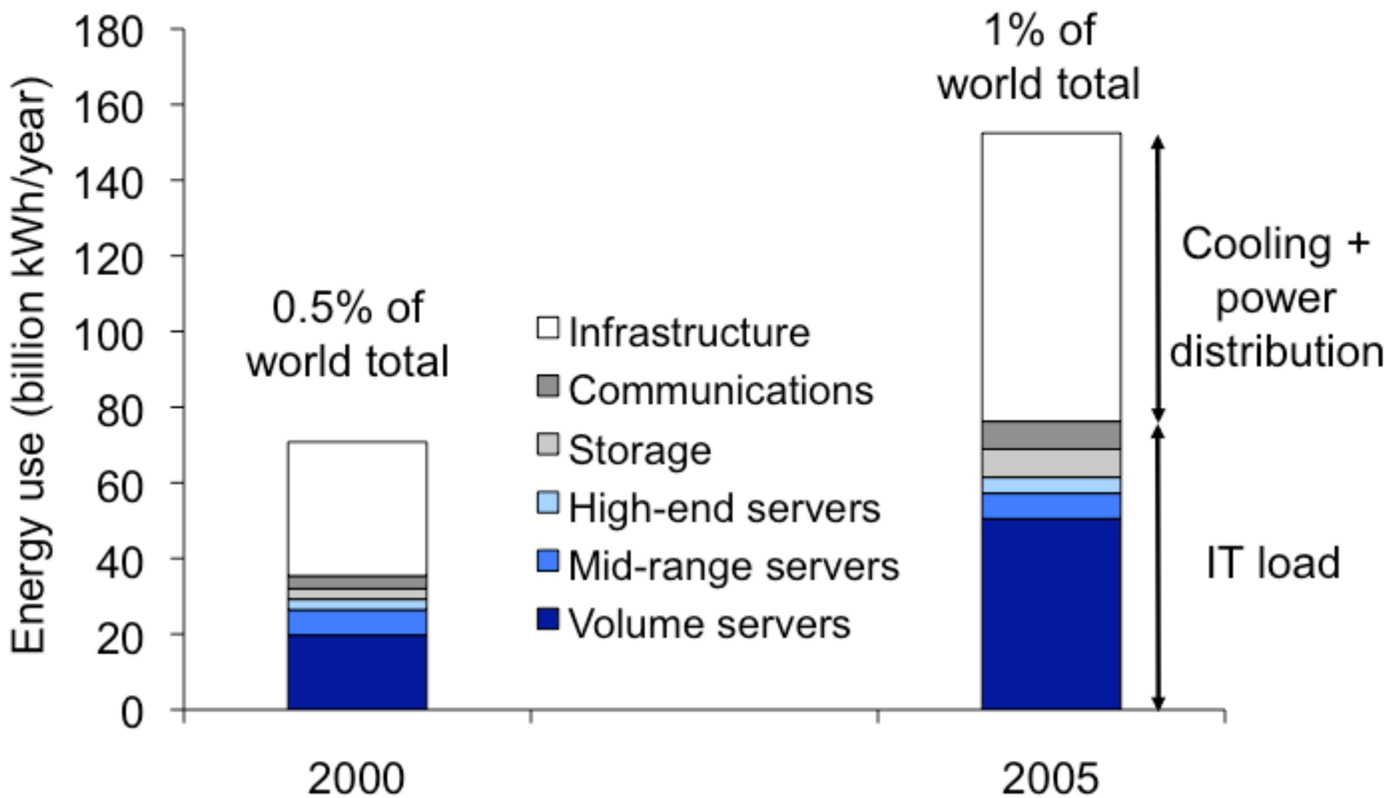


UPS = Uninterruptible Power Supply

PDU = Power Distribution Unit;

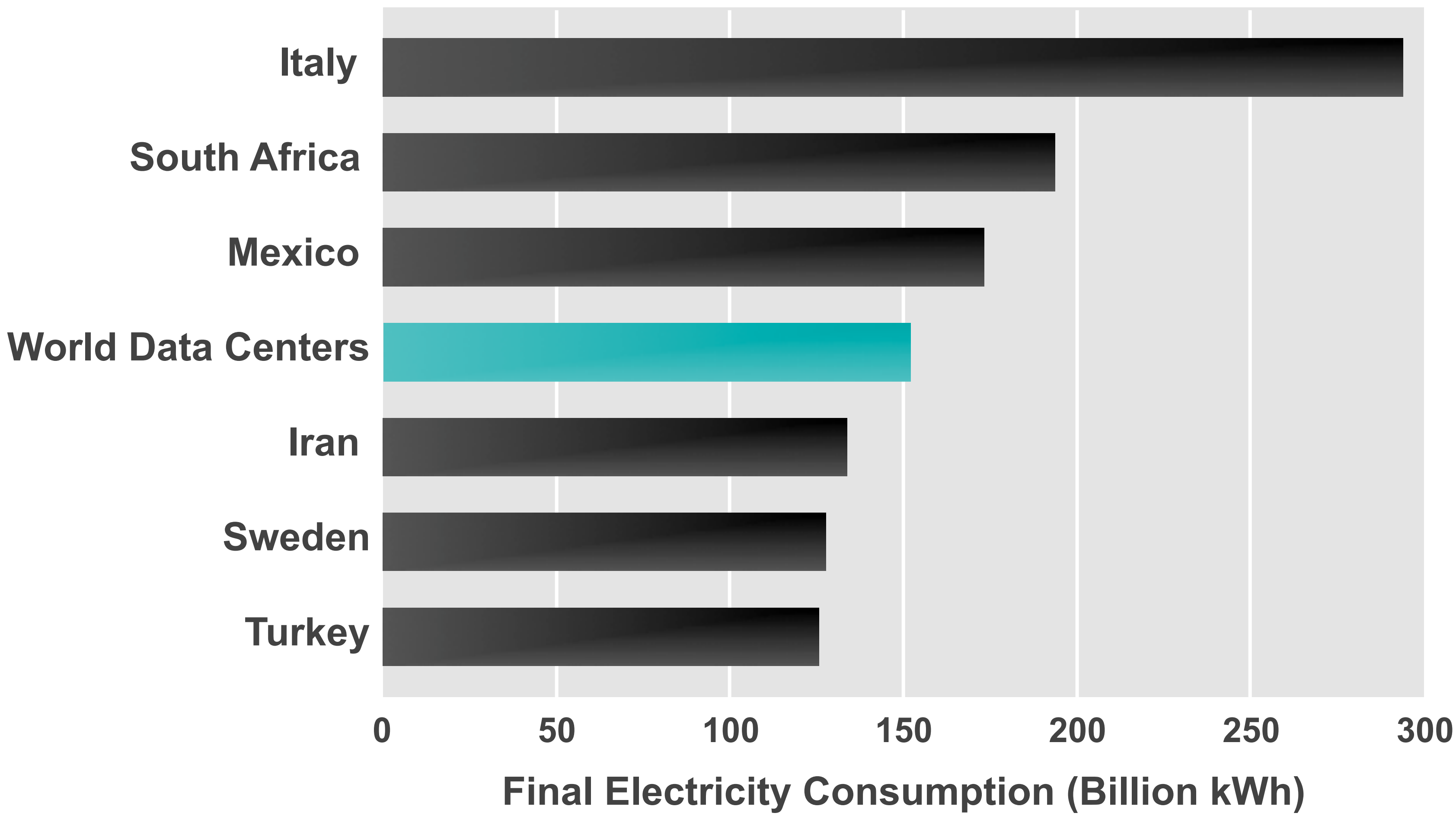
Data centers use electricity. How much?

World data center electricity use, 2000 and 2005



Source: Koomey 2008

How much is 152B kWh?



Source for country data in 2005: International Energy Agency, *World Energy Balances* (2007 edition)

Big issues

- IT service demand is growing rapidly
- Efficiency is improving quickly
- Large efficiency potentials remain
- Misplaced incentives
- Low equipment utilization
- Embedded carbon/energy vs. usage carbon/energy
- Boundaries
  - Direct use (a few percent of electricity use)
  - Indirect effects on the rest of the energy

Delivery of IT services is increasing rapidly

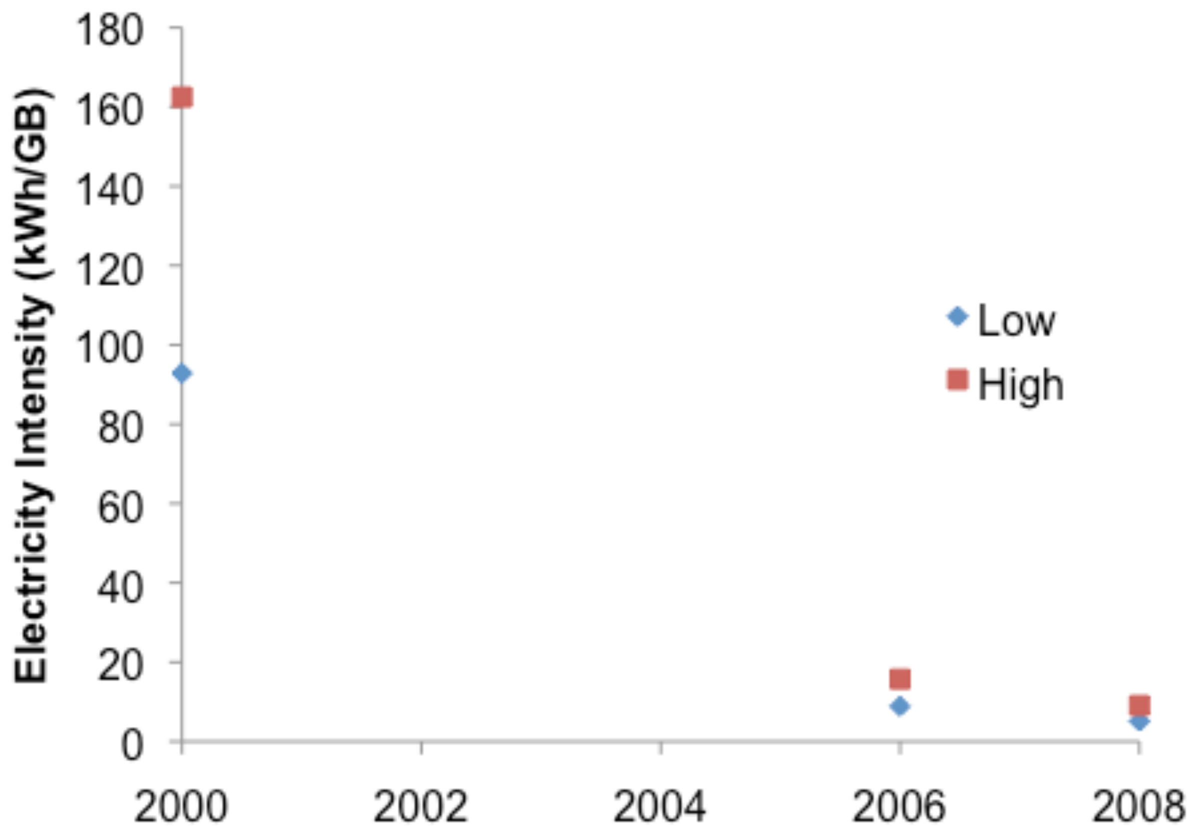
Growing IT service demand

- Odlyzko (http://www.dtc.umn.edu/mints/) shows median growth rates of Internet traffic of about 50% per year from 2002 to 2008
- Computations per PC doubling every 1.5 years since mid 1980s
- Desktop PC installed base up 9%/yr 2000 to 2008–laptops up 24%/year

Information technology is becoming more energy efficient at a furious pace

Internet electricity intensity

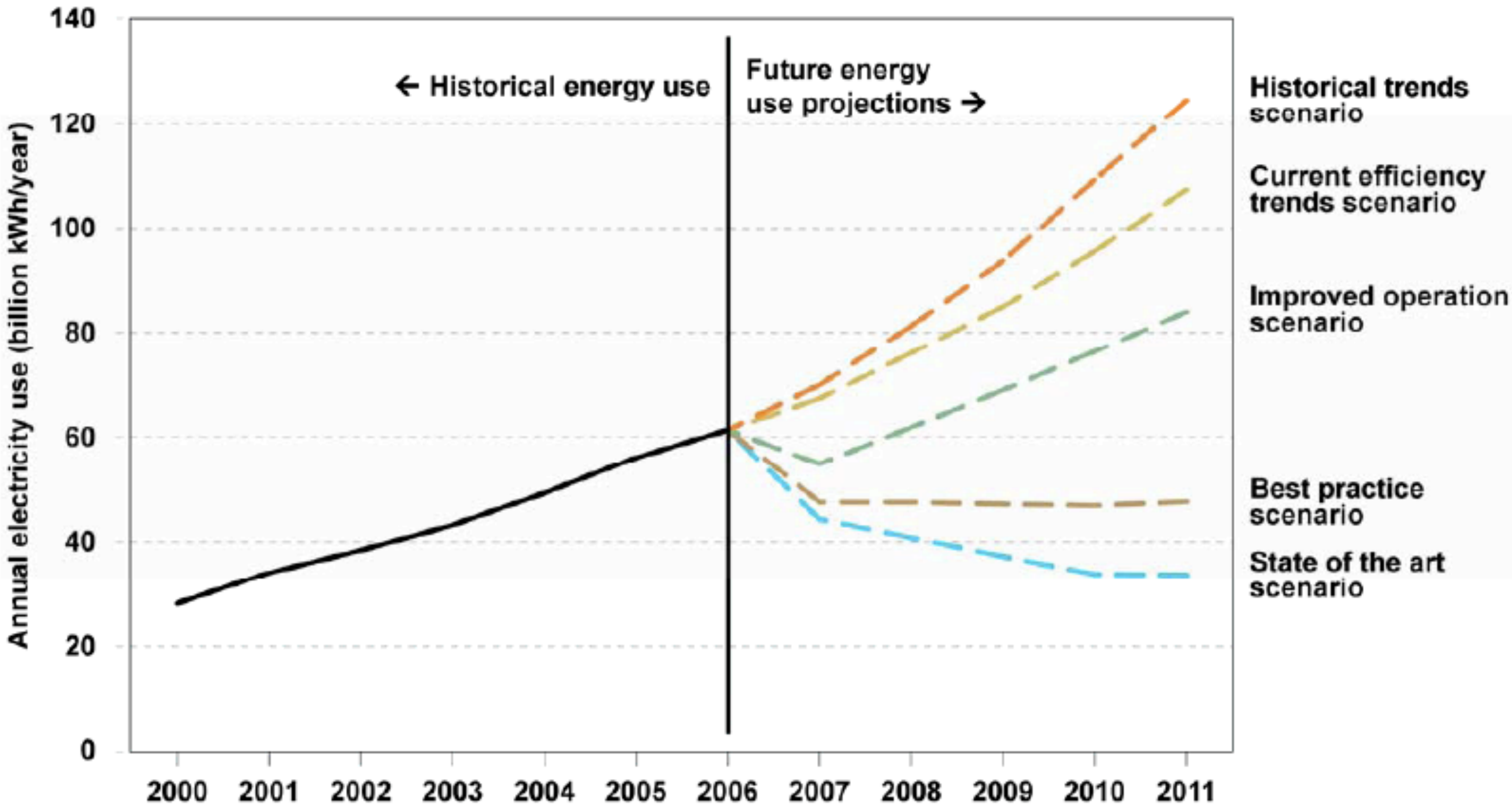
Electricity per GB transferred down 30% per year!



Source: Taylor and Koomey (2008) for 2000 and 2006 data.
Trends for 2000 to 2006 extrapolated to 2008 by JK.

In spite of our historical progress, there's still great potential for improving the energy efficiency of data centers and other IT equipment

Many efficiency opportunities



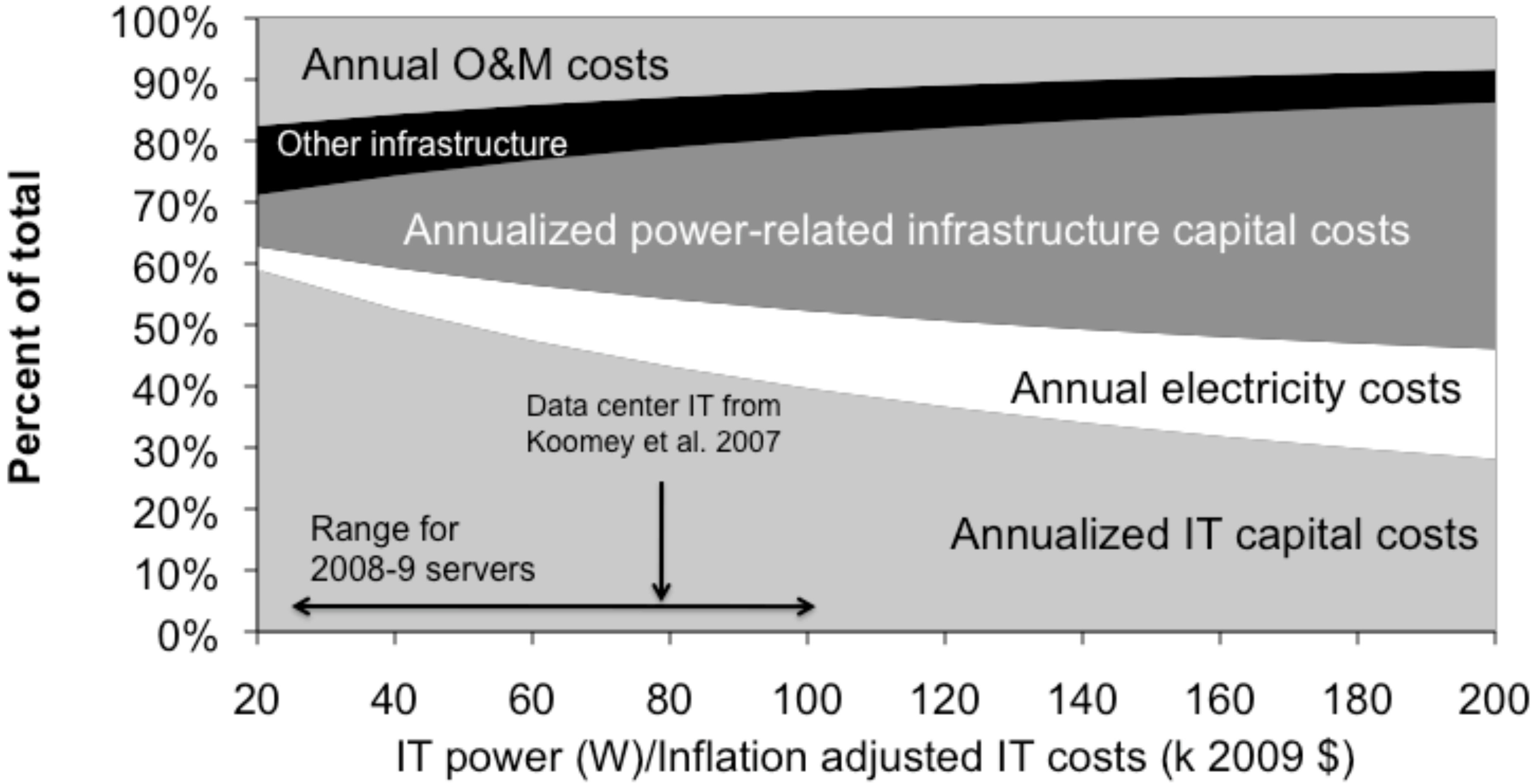
Source: EPA report to Congress on data centers 2007

Improving the energy efficiency of data centers is as much about people and institutions as it is about technology

Misplaced incentives

- Energy, efficiency, and performance metrics not standardized
- Not charging per kW but per square foot
- Split accountability
  - Who pays the bills, IT or facilities?
  - Who bears the risk of failure?
- Hierarchy and culture differences
- Piling safety factor upon safety factor
- Not focusing on total costs for delivering computing services

Annualized data center costs reflect misplaced incentives



Two important equations

$$\frac{\text{Power}}{\text{Server cost}} = \frac{\left(\dfrac{\text{Performance}}{\text{Server cost}}\right)}{\left(\dfrac{\text{Performance}}{\text{Power}}\right)}$$

Power related terms

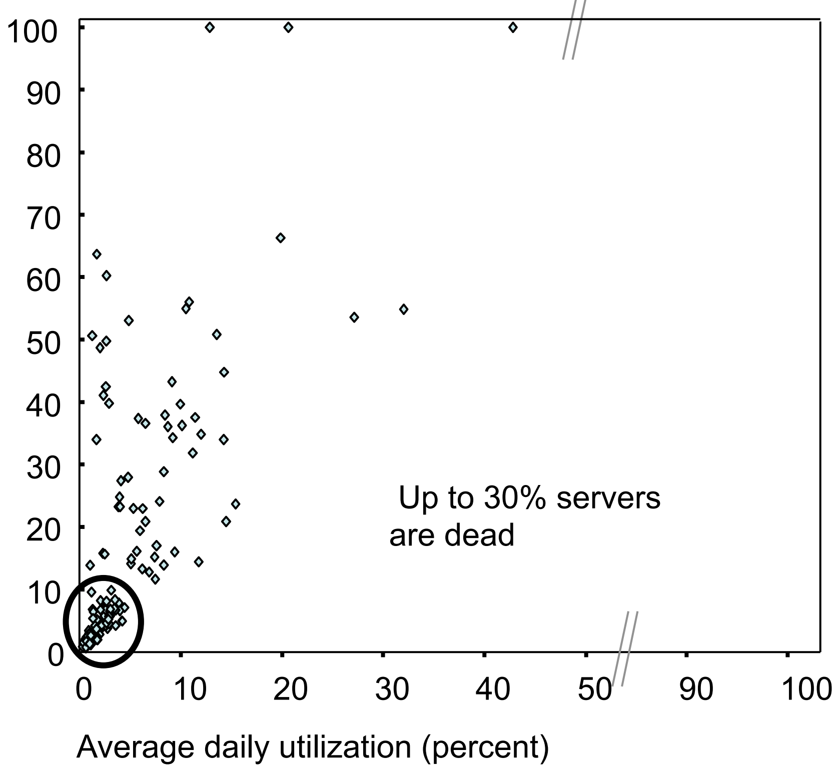
$$\frac{\text{ATC}}{\text{Annual computations}} = \frac{\text{IT} + \text{INF}_{\text{kW}} + \text{INF}_{\text{non-kW}} + \text{EC} + \text{O \& M}}{\text{Annual computations}}$$

Lesson: Whole system redesign is needed to capture efficiency potentials in data centers

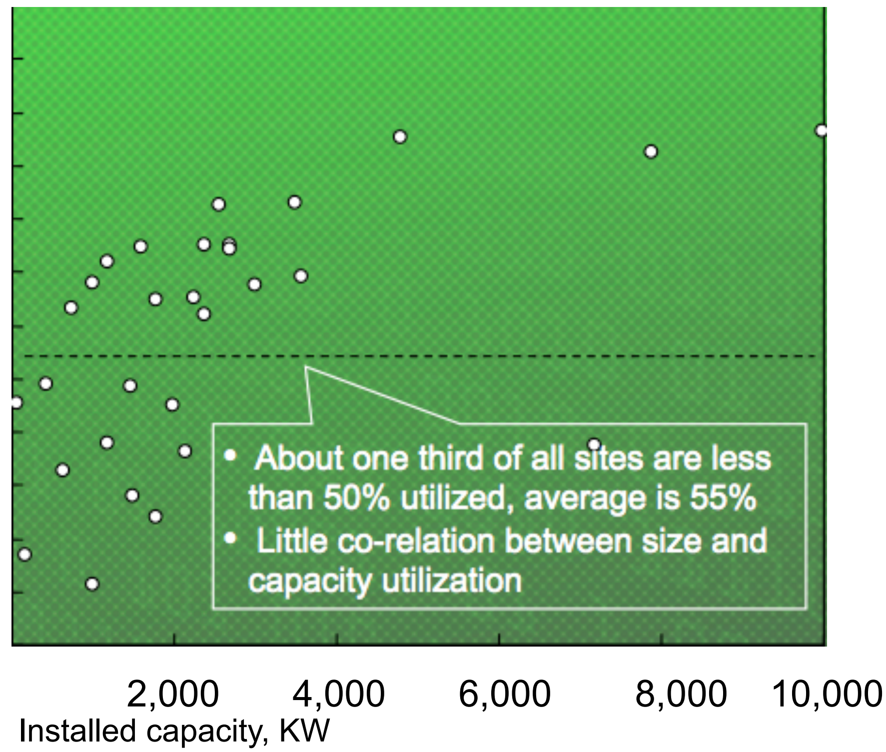
Low utilization is pervasive

DISGUISED CLIENT EXAMPLE

Server utilization remains very low. . .



UPS, cooling, and other facilities are consistently underutilized . . .



A small number of organizations are starting to monitor server utilization, however very few organizations monitor facilities energy efficiency or utilization

* Sample size – 45 data centers

* Source of data: Uptime Institute; Source of original PPT slide: McKinsey and Company

Embedded vs usage C + E

- Direct carbon and electricity use for end-user IT generally more important than embedded C + E, BUT
- Shifting to more mobile devices (very low direct usage) will change that equation
- Direct use still dominant for data centers

The biggest environmental story about information technology (IT) is not direct electricity use (which is relatively small) but how IT affects efficiency in the broader society

Why?

IT magnifies our ability to improve decisionmaking (getting smarter is good) AND

Moving electrons is always less environmentally damaging than moving atoms (dematerializing is good)

Getting smarter

- IT allows better
  - data collection (e.g. wireless sensor nets)
  - real-time control (e.g. industrial processes)
  - analysis (e.g., Wattbot , which helps consumers make better energy choices http://www.wattbot.com/)

Dematerialization

- Lovins: "Move the electrons, leave the heavy nuclei at home"
- Examples
  - Telecommuting
  - Telepresence (video conferencing)
  - Sending PDFs instead of documents

Example: paper vs. PDF

- Mass of paper = 5 g/sheet
- Mass of electrons to move a 1 MB PDF file of that page (based on average network electricity intensity of 7 kWh/GB) is 1.7×10^{-5} g
- Ratio of paper mass to electron mass ~ 300,000

Conclusions

- Direct electricity use of IT is important BUT
- Indirect effects on economic productivity and other energy uses are large and mustn't be ignored
  - Getting smarter
  - Dematerialization
- Making IT significantly more efficient requires whole system, clean slate redesign focusing on
  - software and hardware
  - people and institutions
  - direct and indirect effects

Key web sites

- EPA on data centers + 2007 Report to Congress http://www.energystar.gov/datacenters
- LBNL on data centers: http://hightech.lbl.gov/datacenters.html
- Summary of US total IT electric use in 2000: http://enduse.lbl.gov/Projects/InfoTech.html
- Wattbot: http://www.wattbot.com/

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