Energy Consumption by Commercial Office and Telecommunications Equipment

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Arthur D. Little, Inc.
Acorn Park
Cambridge, Massachusetts
02140-2390

Kurt Roth, Ph.D.
Fred Goldstein
Jonathan Kleinman

The remarkable growth of the Internet since the mid-1990s led to plausible speculation that office and telecommunications equipment annual energy consumption (AEC) had - and would continue - to grow dramatically.

- **Dramatic growth in Internet-related equipment installed base since ~1995, particularly servers, computer network equipment**
- **Continued explosive e-Commerce growth would drive further increases in equipment installed base**
- **Data Center build-out projected to reach 25 million ft^2 by 2003, with very high power densities (>100W/ft^2)**
- **Much Internet-related equipment operates around the clock**
- **The Internet could have a major impact of national electricity consumption**

In 1999, Mills and Huber posited that the "Internet" consumed ~8% of U.S. electricity in Y1998, and that this would likely grow to account for 30 to 50% of national electricity consumption by 2010 or 2020.

The U.S. Department of Energy desired a better understanding of current and future commercial office and telecommunications equipment energy consumption to assist in their planning processes.

We developed AEC estimates for more than thirty types of equipment.

Displays:

- Monitors
- General Displays

Personal Computers:

- Desktop
- Laptop

Server Computers:

- "High-End" Servers
- "Mid-Range" Servers
- "Workhorse" Servers
- "Low-End" Servers
- Data Storage

Printers

- Laser Printers (several classes)
- Inkjet Printers
- Impact Printers
- Line and "other" printers

Copiers (Several Classes)

Telephone Network Equipment

- Cell Site Equipment
- Transmission (Fiber Optic Terminals)
- Public (Analog) Phone Network
- Private Branch Exchanges
- Wireless Phones

Computer Network Equipment:

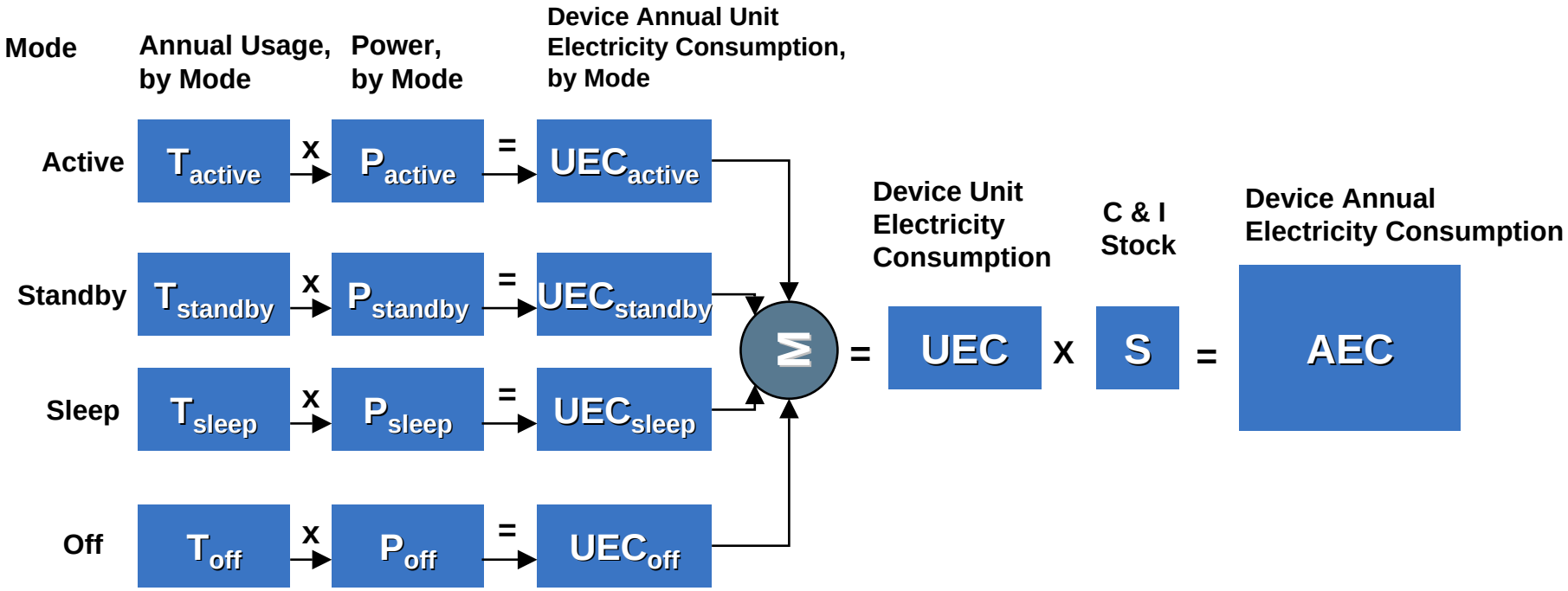
- LAN Switches
- Routers
- Hubs
- WAN Switches
- Remote Access Servers
- Cable Modem Termination Systems

Uninterruptable Power Supplies

Other

- Facsimile Machines
- Point-of-Sales Terminals
- Typewriters
- Automated Teller Machines
- Scanners
- Very Small Aperture Terminals
- Supercomputers
- Smart Handheld Devices
- Dictation Equipment
- Handheld Devices
- Workstations
- Desktop Calculators
- Handheld Calculators
- Voice Mail Systems

The Annual Energy Consumption (AEC) estimates generally came from a bottom-up analysis of the stock, usage patterns and power draw (by mode) of the different equipment types.



Equipment installed base (stock) estimates typically came from reports of installed base or sales data (summed over product lifetime).

Stock Includes

- Equipment in commercial and industrial buildings
  - Difficult to differentiate between commercial and industrial stock
- Telecommunications equipment not in buildings (e.g., fiber optic terminal in manhole)

Equipment *usage* estimates reflect a combination of *in situ* audits of usage and ADL estimates.

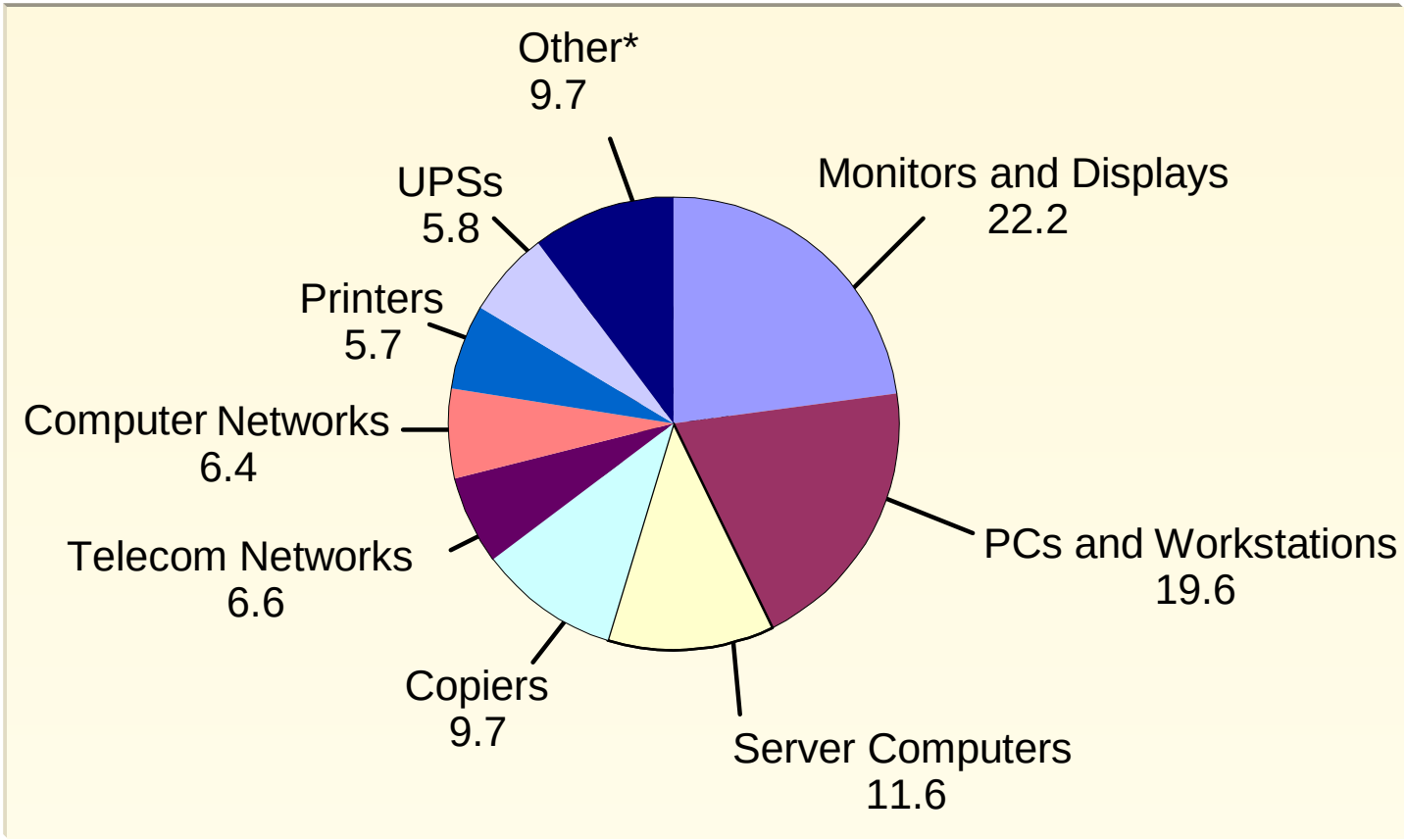
Usage Modes

- *Active:* Carrying out intended operation (copier copying)
- *Standby:* Ready to carry out intended operation (copier warm)
- *Sleep:* On but not ready to carry out intended operation (copier on but fuser roll cold)
- *Off*: Turned off, plugged in (copier off, but plugged in)

We considered power draw estimates from multiple sources, using actual power measurements whenever possible and selecting the most appropriate data.

- LBNL
- Swiss Federal Office of Energy
- Industry contacts
- Manufacturers' Literature
- European Union Study (MACEBUR)
- Hosni (Kansas State)
- In-House Measurements
- etc.

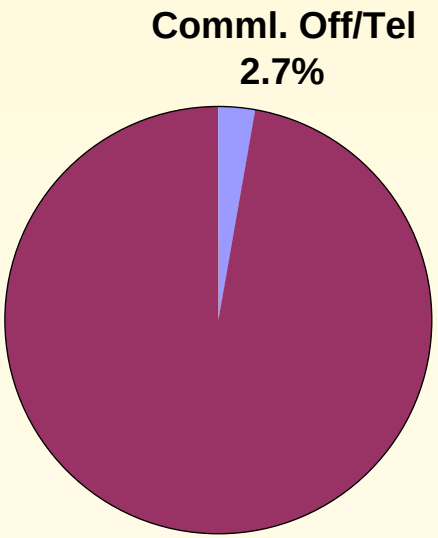
Commercial Office and Telecommunications equipment consumed *97TW-h* in Y2000.



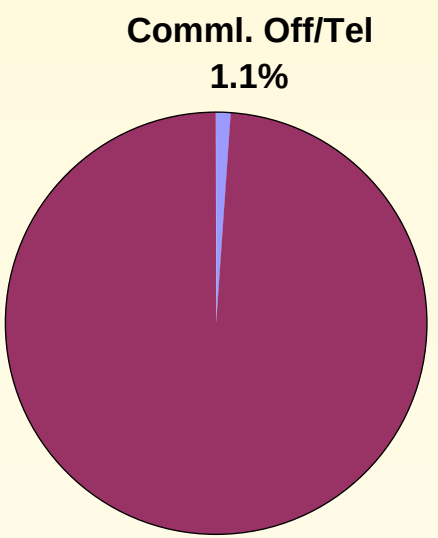
*Other includes: Facsimile machines, desktop and handheld calculators, point-of-sale (POS) terminals, electric typewriters, automated teller machines (ATMs), scanners, very small aperture terminals (VSATs), scanners, supercomputers, voice mail systems (VMSs), smart handheld devices, and dictation equipment.

Commercial Office and Telecommunications equipment electricity consumption represents just under *3%* of national electricity consumption, and a little over *1%* of national energy consumption

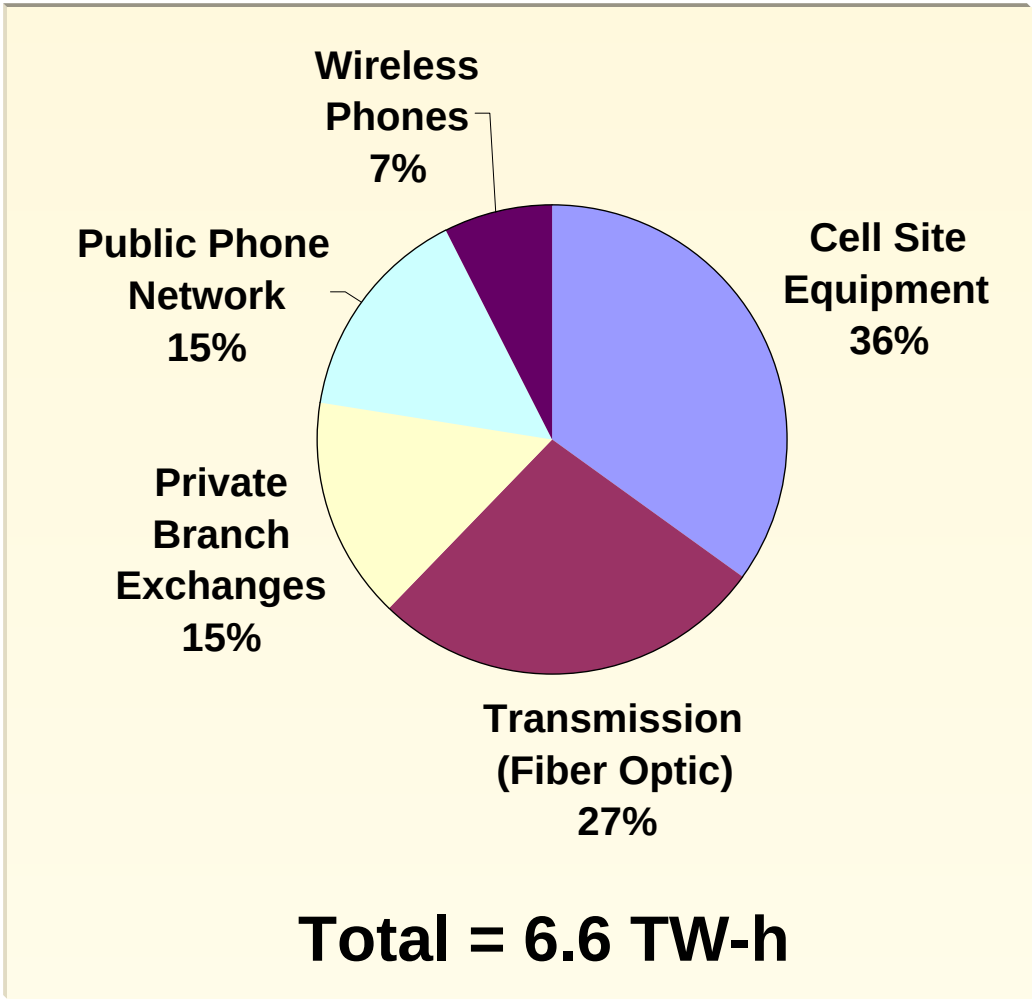
Electricity Consumption



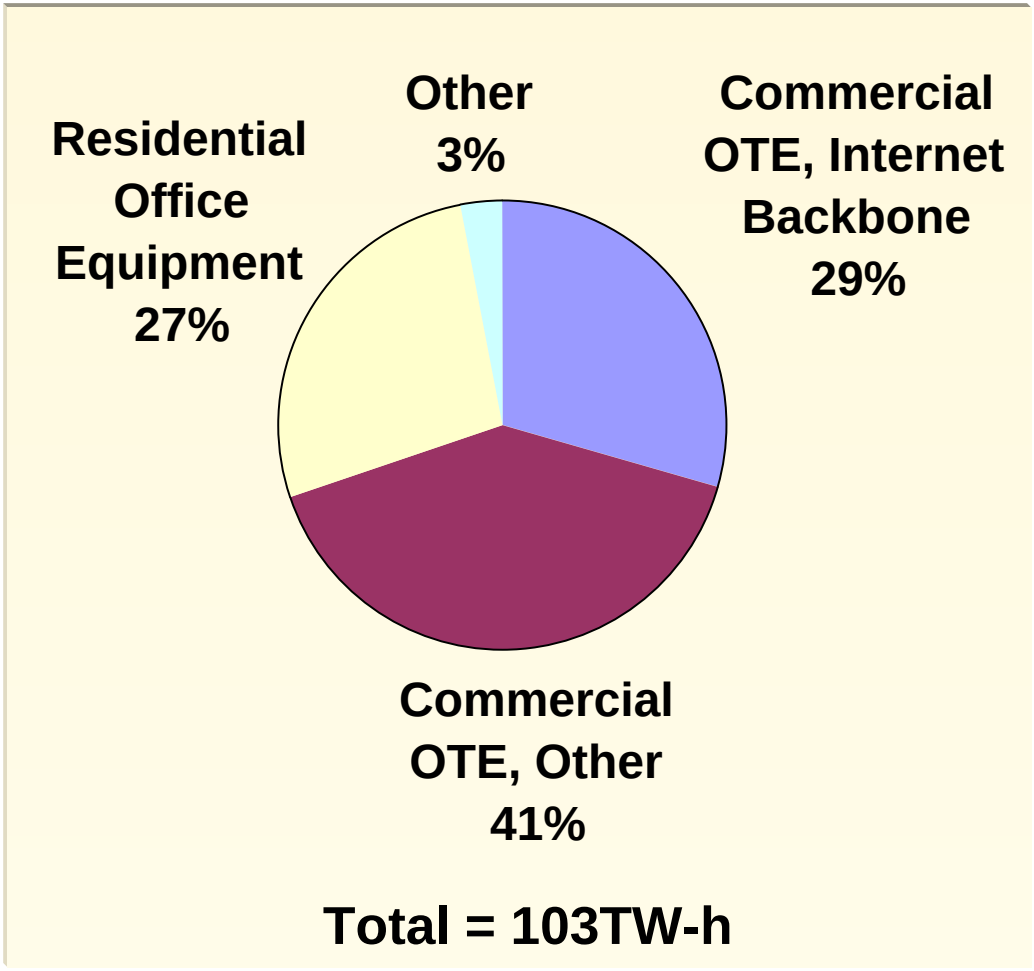
Primary Energy Consumption



This study includes the first bottom-up estimate of commercial telecommunications network equipment - *6.6TW-h* in Y2000.



An upper-bound estimate shows that the U.S. "Internet" consumed no more than *103TW-h* in Y2000.



Internet Backbone Includes: Server Computers, Data Storage, Computer Network Equipment, Telephone Network Equipment, UPSs.

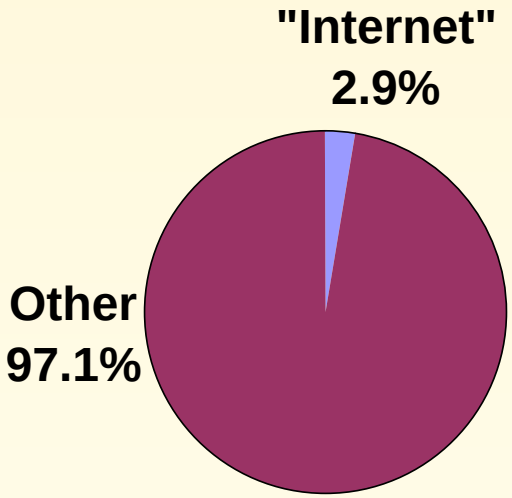
Commercial OTE, Other Includes: PCs (desktop and laptop), Monitors, General Displays, Smart Handheld Devices, Workstations.

Residential Office Equipment Includes: PCs (desktop and laptop), displays (Meier, 2001; preliminary upper bound estimate).

Other Includes: Residential broadband (Cable Model, DSL), residential wireless phone (chargers), residential smart handheld devices (e.g., Palm Pilot), Internet appliances (e-mail terminals, thin enterprise clients, iTV-enabled devices)

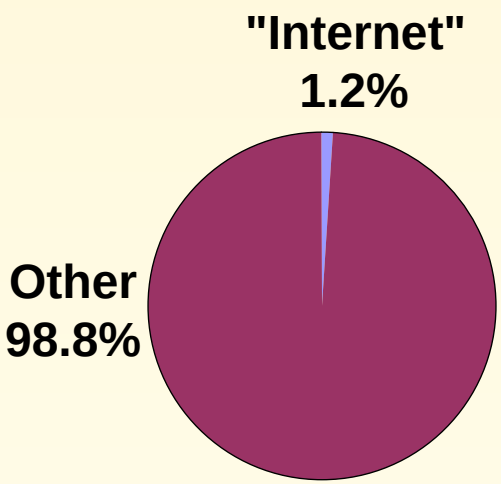
Placed in a national context, the "Internet" upper-bound estimate represents about *3%* of electricity consumption, and more than *1%* of primary energy consumption in Y2000.

Electricity Consumption



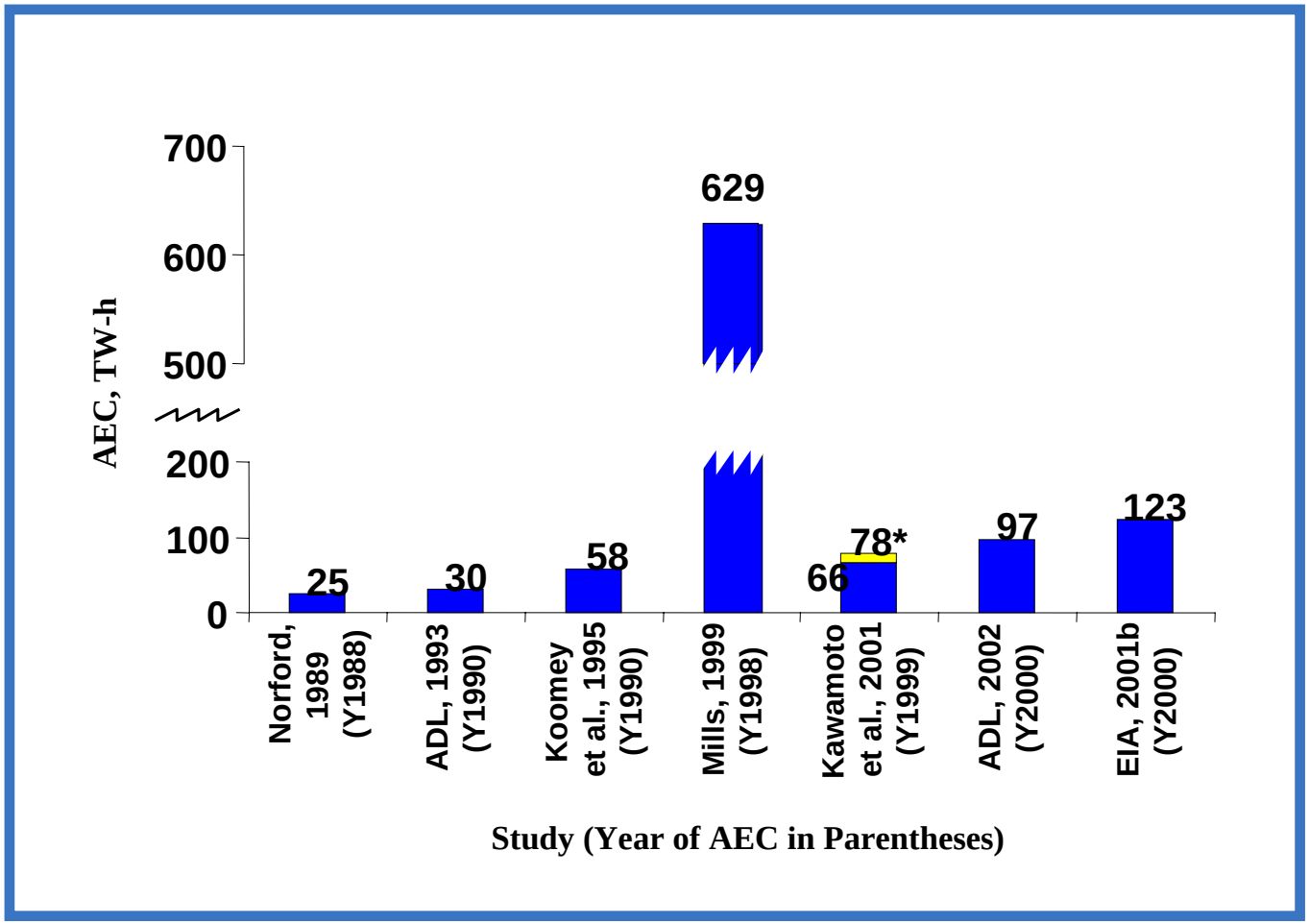
Total = 3,610 TW-h

Energy Consumption



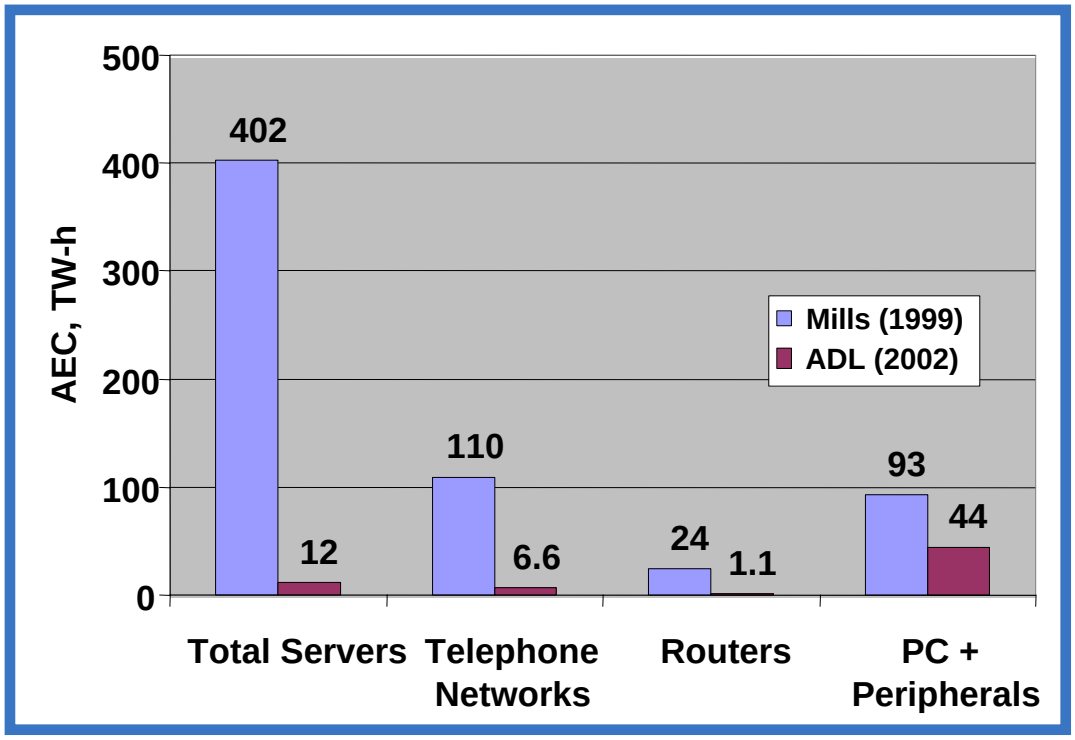
Total = 97.7 quads

The current AEC results are generally consistent with other recent AEC estimates, excepting Mills (and Huber).



*Includes telephone central office AEC estimate of Koomey et al. (1999)

The Mills (1999) AEC estimate is much greater than any other study, reflecting dubious methodology.



- *Mills Consistently selects equipment with greatest power draw in class and extrapolates to entire device population*
  - Models all “mainframe” computers with the power draw of a supercomputer
  - All routers modeled by backbone routers; most are edge routers, i.e., <40W
  - All telephone central offices approach (may exceed) the power draw of the largest CO in the
  - All PCs (including monitors and printers) draw ~the same power as a PC, 17-inch (430mm) monitor, and a laser printer printing continuously

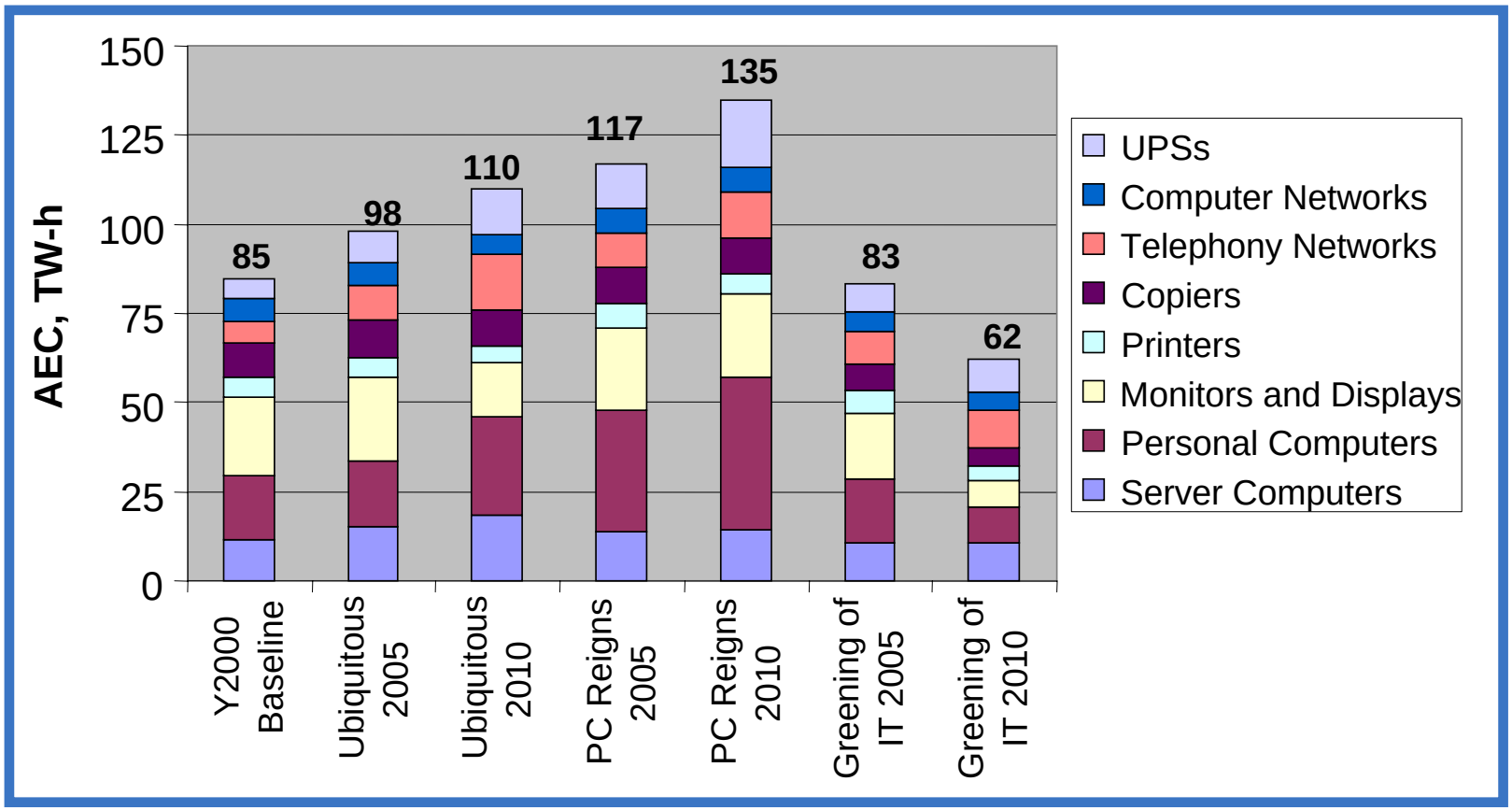
We developed three distinct future scenarios to generate a range of bottom-up AEC estimates for key equipment types in Y2005 and Y2010.

- ***Ubiquitous Computing:***
  - Continuous connectivity becomes a way of life, via portable computers, smart handheld devices, wireless phones with advanced functionality.
  - Internet access quality (bandwidth) and reliability paramount
- ***PC Reigns:***
  - Computing remains anchored to the desktop PC – most workers have a PC
  - PC performance highly valued
  - Widespread high-bandwidth connectivity to enable effective exchange of large quantities of data and programs run efficiently by local PCs (e.g., video)
- ***Greening of IT:***
  - European Community and Japan ratify the Kyoto Accord
  - Energy consumption of office and telecommunication equipment becomes a major concern
  - Power-aware design becomes the rule for office and telecommunications equipment hardware and consumables

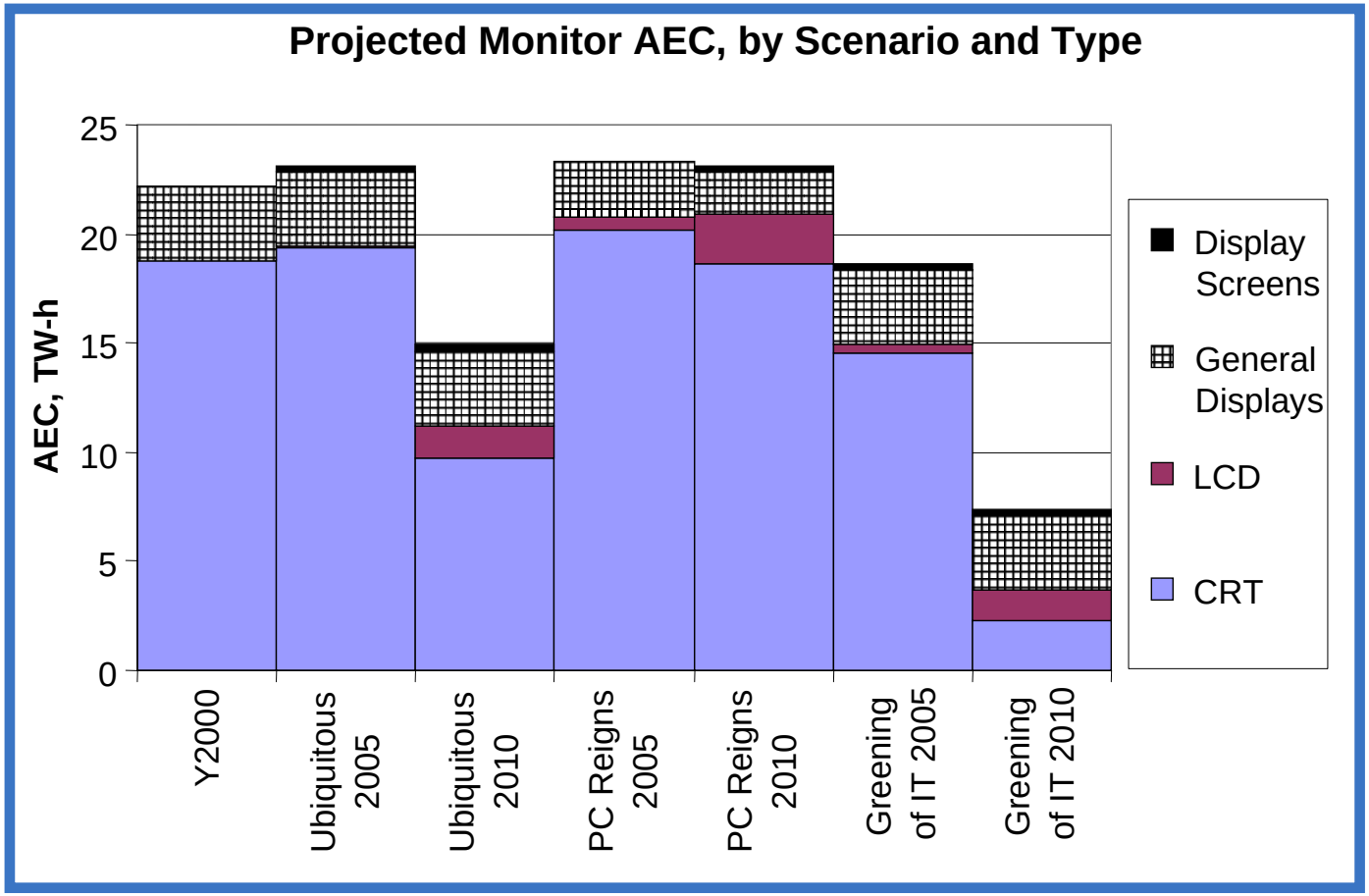
We carried out brainstorming sessions to broaden and enrich our vision of possible futures, i.e., potential trends and technologies - and to enhance our AEC projections.

- ***Key General Trends:***
  - IT integration into society (e-commerce, connectivity)
  - New devices/applications (powerful portable devices, FTTH/C)
- ***Future/Nascent Technologies:***
  - New microprocessors (high performance, adaptable architectures)
  - Monitors (LCDs, OLEDs)
- ***Projections:***
  - Bottom-up process
  - Estimates of future equipment stocks, usage patterns (by mode) and device power draw

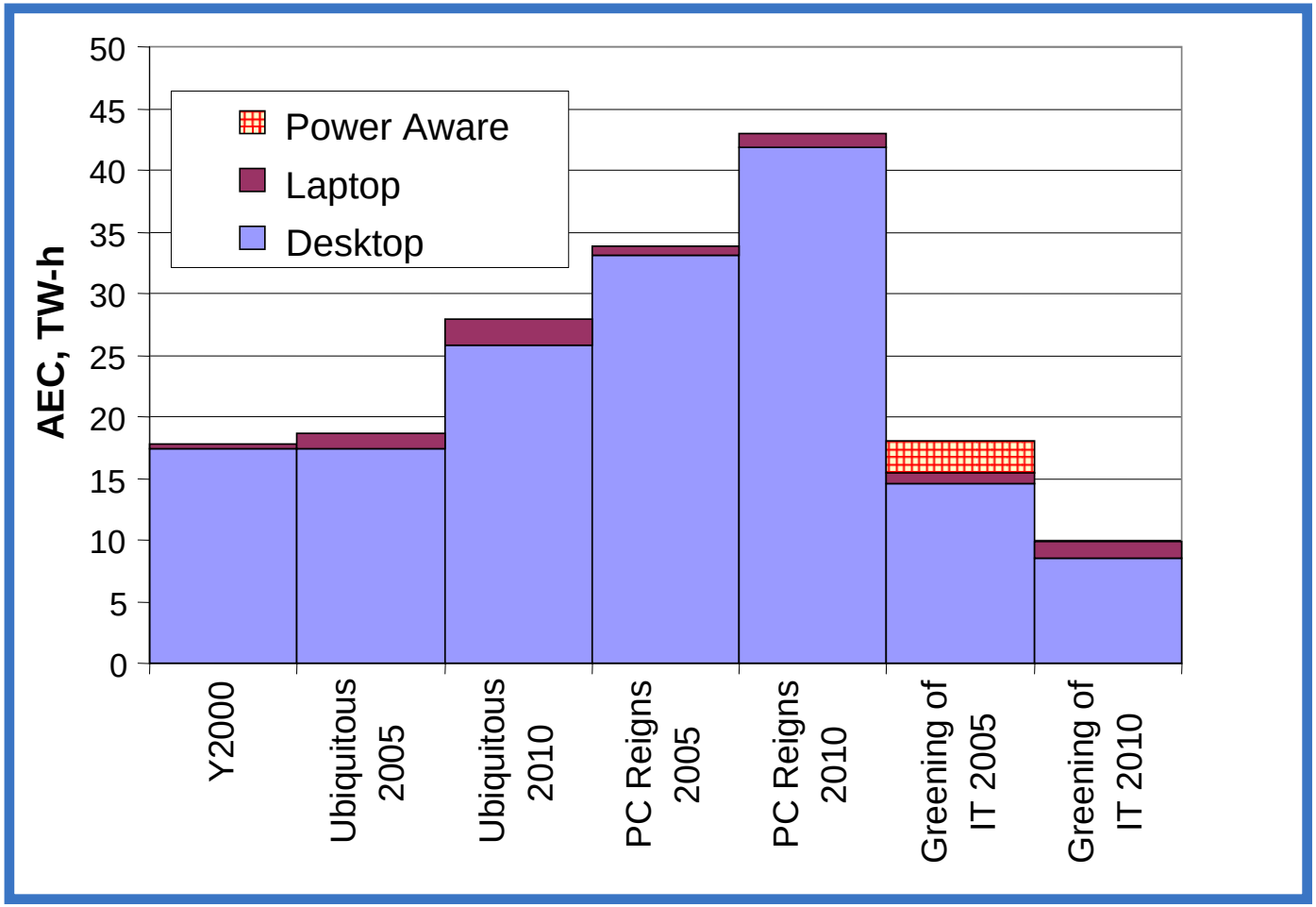
Three scenarios for future equipment electricity consumption show a wide range of potential consumption levels for Y2005 and Y2010. In Y2010, OTE could account for as much as 3.5% - or less than 2% - of national electricity consumption.



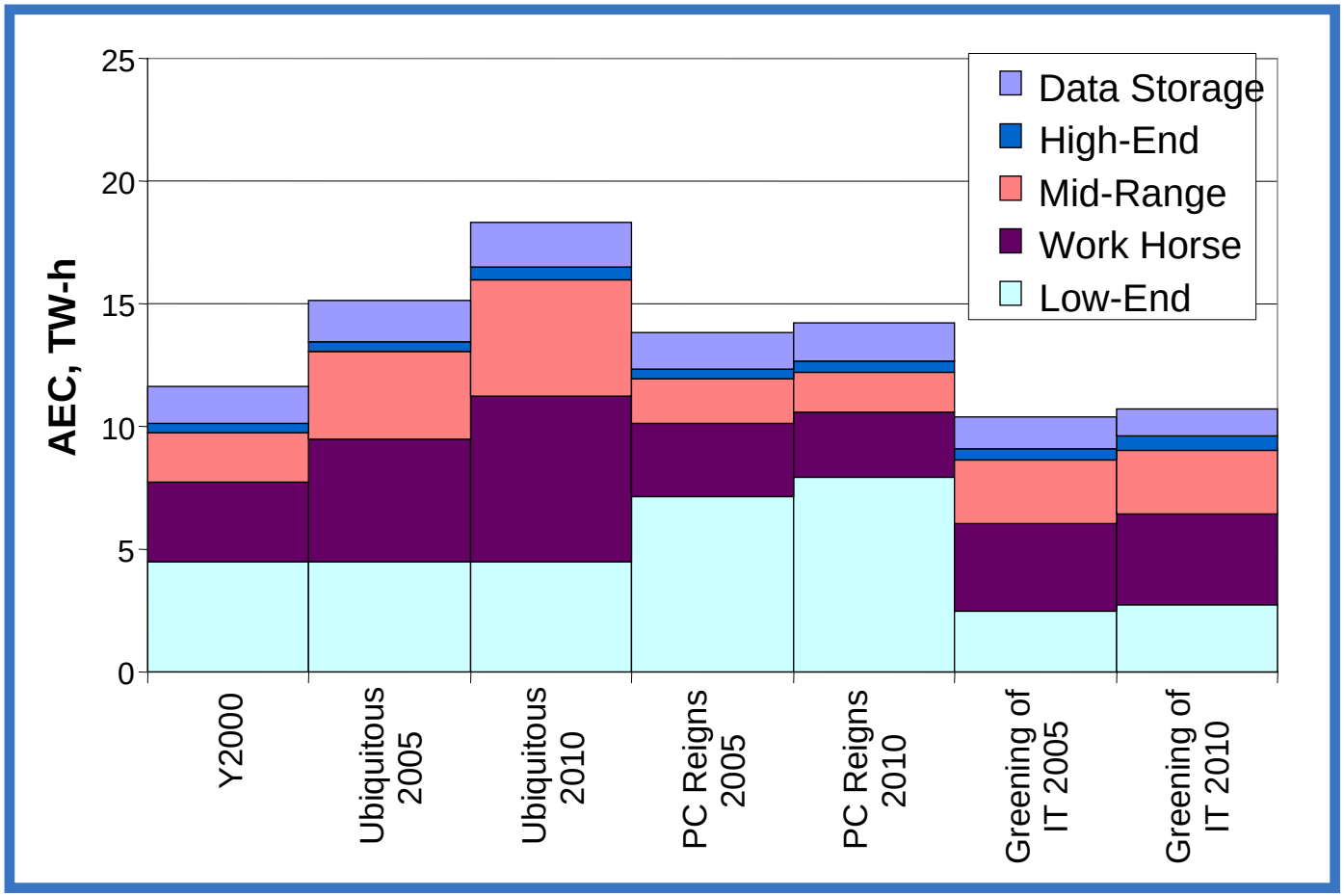
The market penetration of LCDs, *ENERGY STAR*(R)-enabled rates, and the size of future CRTs will have the greatest impact upon monitor AEC.



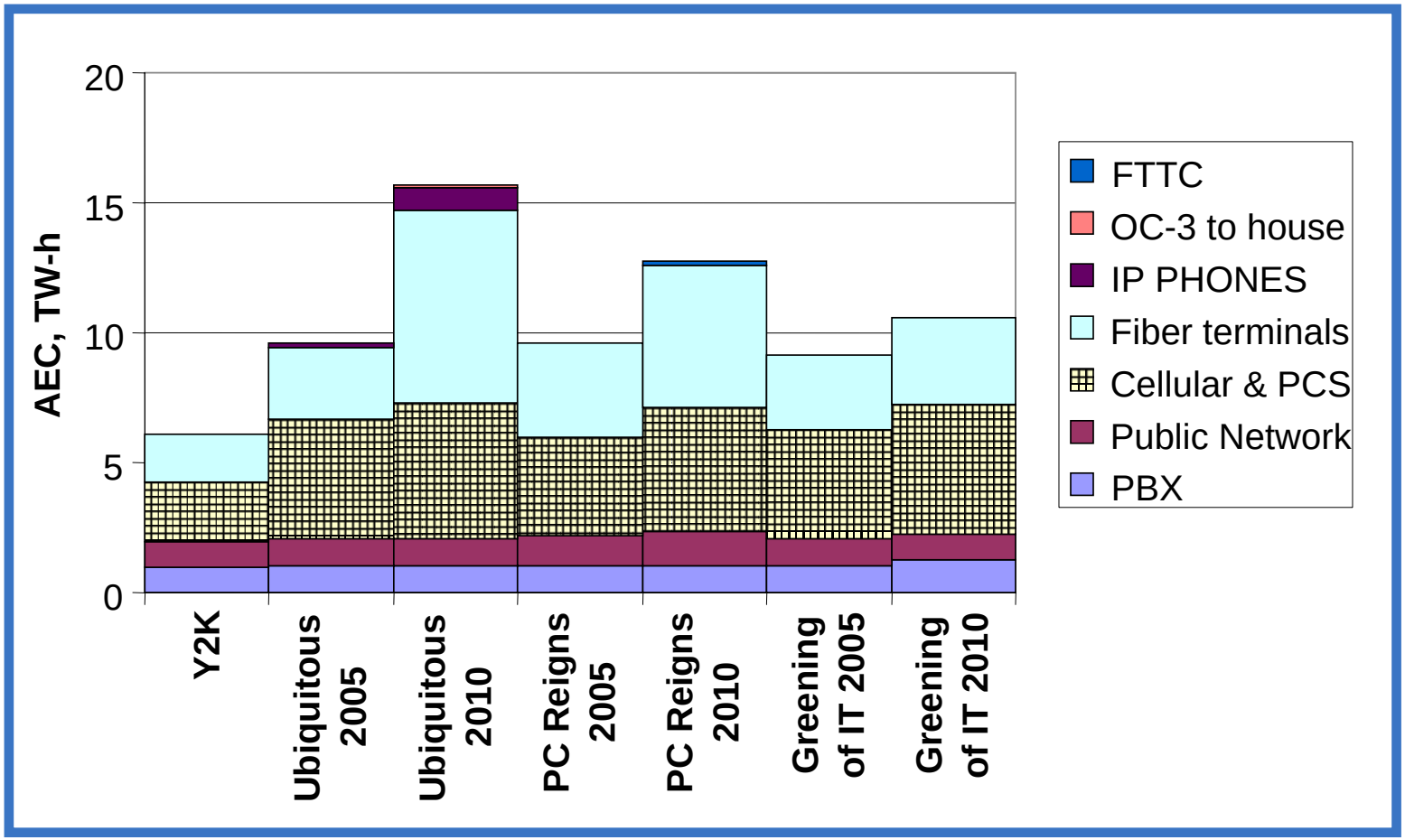
Key drivers for future PC AEC are the stock of mobile computing device, future microprocessor power draw, and *ENERGY STAR*(R)-enabled rates (~25% at present).



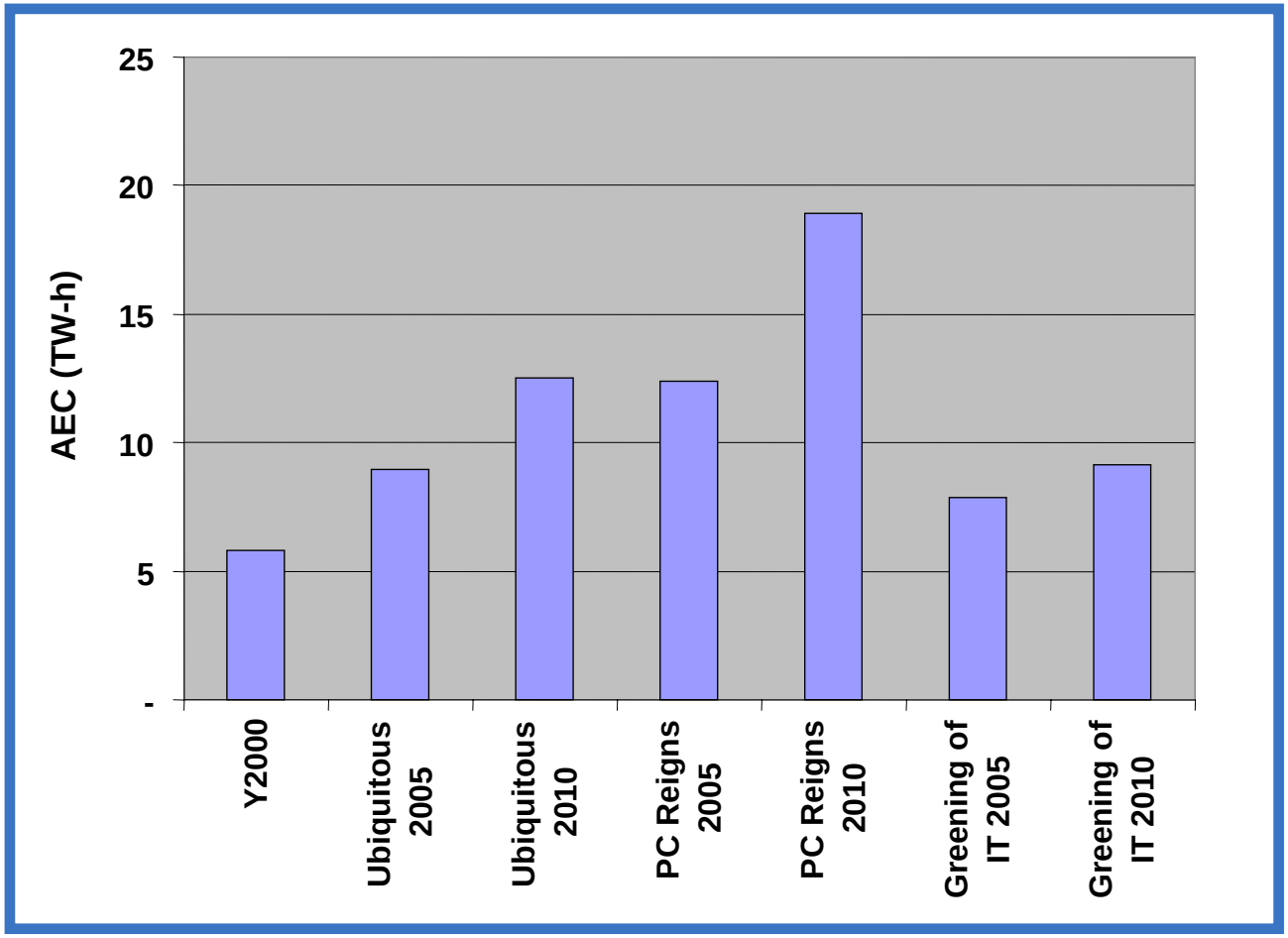
The growth rate of data access, migration of the stock between different servers “classes”, and low-end server power draw will strongly influence future server computer AEC.



Telephone networks' AEC will increase substantially in all three scenarios due to mobile telephony expansion (3G) and continued deployment of fiber-optic equipment (more sites, higher bandwidth - e.g., OC-768).



Increasing societal integration with the Internet will drive demand for higher Internet backbone reliability, causing UPS AEC to grow in all scenarios.



The *indirect* impact of office and telecommunications equipment upon electricity consumption likely exceeds the *direct* impact. Our study only touched on the main issues - much further work remains.

- ***Macroeconomic Effects:*** Possible Acceleration in Decrease in Macroeconomic Energy Intensity (e-Commerce, de-materialization, etc.).
- ***Energy to Manufacture Equipment:*** Using CMU supply chain model, embodied energy ~same order as direct energy consumption.
- ***Peak Load Impact:*** Responsible for ~3 to 4% of national peak electricity demand - from direct power draw, poor power factors, higher A/C loads.
- ***HVAC Impact:*** Likely increase on the order of 5-10% of equipment electricity consumption, due to concentration of office equipment in office buildings.
- ***Equipment Disposal:*** Hundreds of millions of devices to be discarded over this decade, most **not** recycled

Commercial office and telecommunications equipment account for a small portion of national electricity and energy consumption in Y2000.

- ***National Electricity Consumption:*** ~2.7%
- ***National Energy Consumption:*** ~1.1%
- ***Relative to Commercial Buildings Electricity Consumption:*** ~9%
- ***Upper Bound on "Internet" Electricity Consumption:*** ~2.9% (of total delivered electricity)
- ***Indirect Energy Consumption Impacts Appear Substantial:*** Possible change in macroeconomic "Energy Intensity"; equipment embodied energy

Scenario-based projections suggest that commercial office and telecommunications equipment will continue to account for a small portion of electricity and energy consumption in Y2005 and Y2010.

- ***Y2010 Range, Electricity Consumption: 1.6% to 3.5%***
- ***Y2010 Range, Energy Consumption: 0.7% to 1.5%***
- ***Telecoms and UPS AEC will grow in all scenarios***
- ***All other AECs depend upon technological and larger-scale trends***

Our study identified several areas for future research in Office and Telecommunications Energy Consumption.

- ***Indirect Impacts:*** Particularly Macroeconomic Energy Intensity and OTE Manufacturing Energy.
- ***Energy Savings Opportunities:*** ADL has begun study, funded by DOE.
- ***Additional Equipment Usage Surveys:*** Very large impact (up to 50%) on AEC of some equipment types (copiers, PCs, Monitors).
- ***Detailed Investigation of "Public" and "Transmission" Phone Networks***

The Department of Energy, Office of Building Technology, State and Community Programs, funded this research.

Dr. James Brodrick (DOE) oversaw this assignment, and provided input that helped to shape the approach, execution, and documentation of this project.

The project team included several people from ADL:

Case Leader: Kurt Roth

Case Team: Fred Goldstein, Jon Kleinman

Director-In-Charge: Bob Zogg

The report is available in .PDF format on the web at:

http://www.adltechnology.com/pdfs/energy_consumfinal.pdf

Our report also benefited from the input of many reviewers.

Thank You All!

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