Chapter 11:
Green Computing

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Outline

1. Abstract
2. Green computing architecture
3. Regulations and industry initiatives
4. Approaches to green computing
5. Conclusion
6. Reference

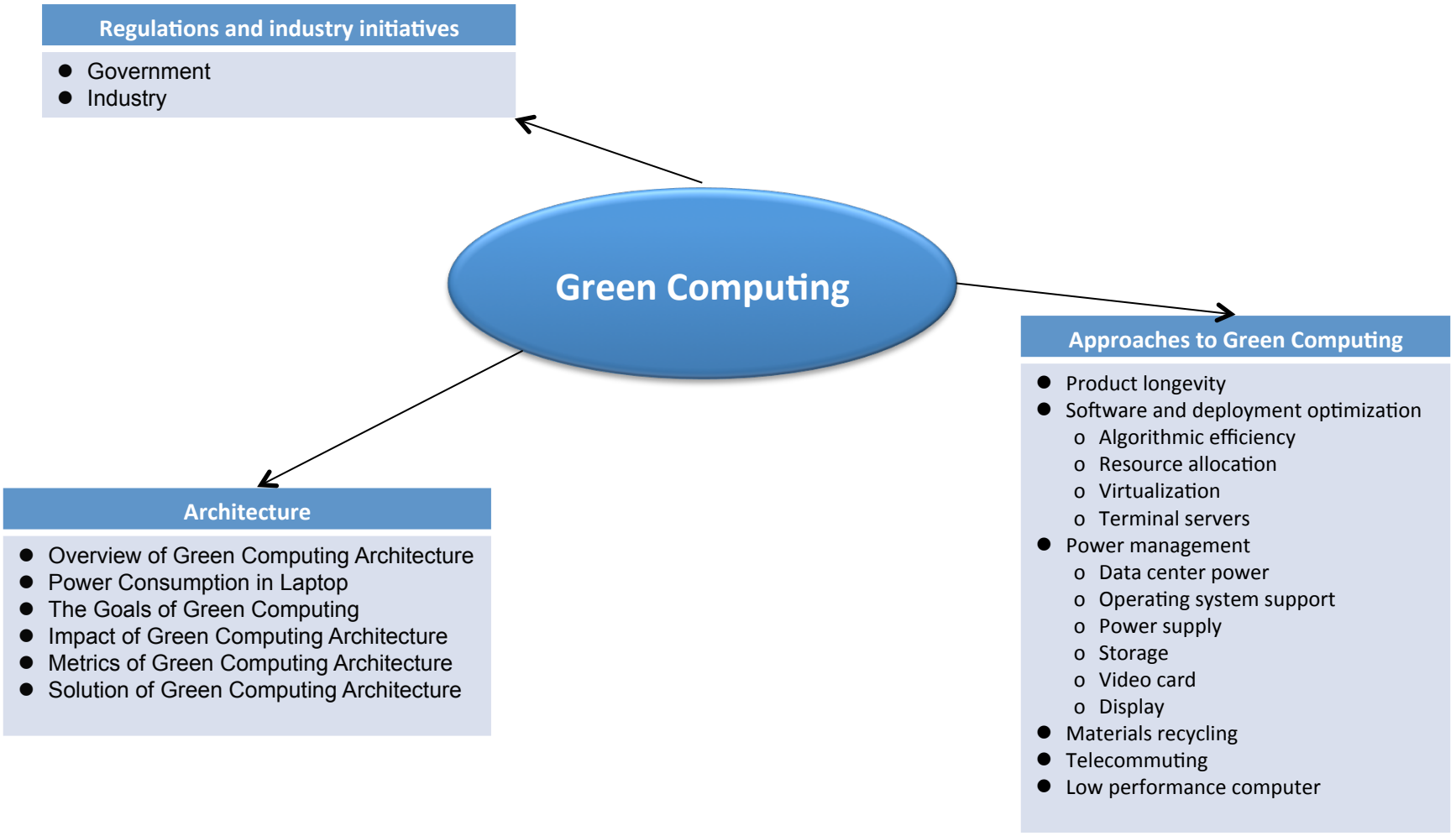
1. Abstract

- In 1992, the US Environmental Protection Agency launched Energy Star, a voluntary labeling program which is designed to promote and recognize energy efficiency in monitors, climate control equipment, and other technologies.
- “Green computing" was probably coined shortly after the Energy Star program began.
- Energy management has always been an important topic for laptop manufacturers, who have been working on this for years as they struggled to manage weight versus battery life issues.

Definition of Green Computing

- Green computing is the study and practice of using computing resources efficiently.
- The primary objective of such a program is to account for the triple bottom line (or "People, Planet, Profit").
- Modern IT systems rely upon a complicated mix of people, networks and hardware; as such, a green computing initiative must be systemic in nature, and address increasingly sophisticated problems.

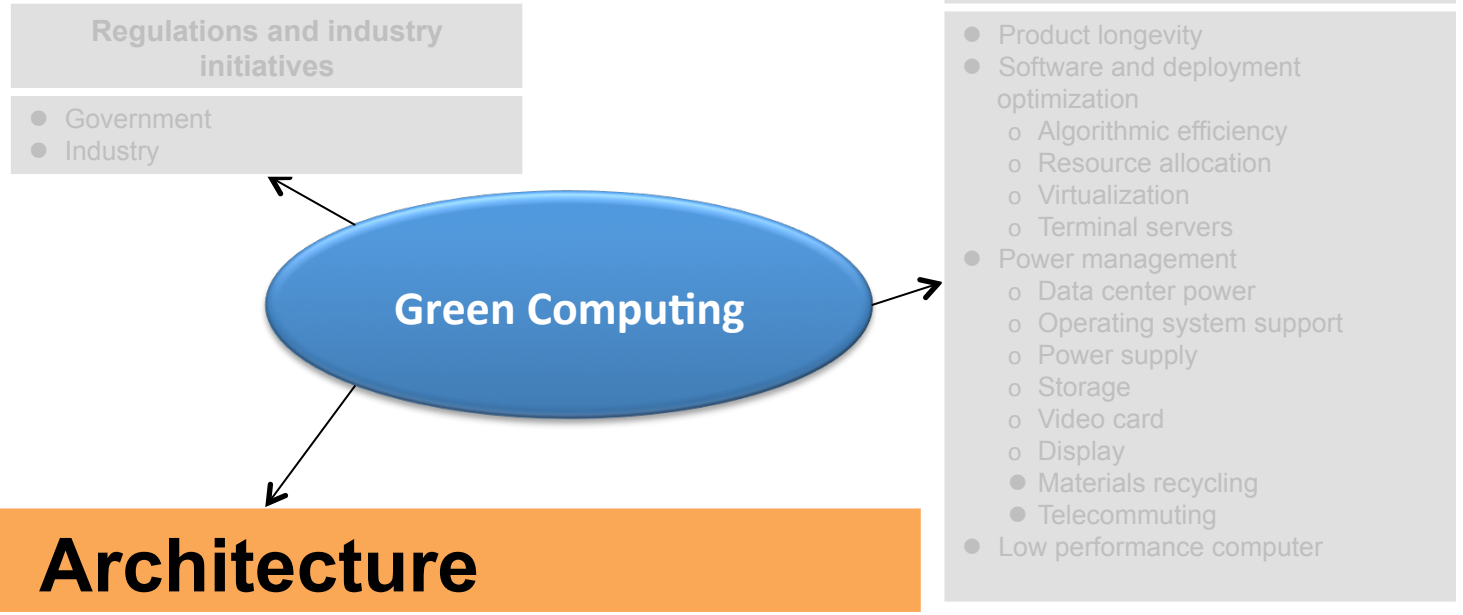
Green Computing



Overview of Green Computing

- Green computing or green IT, refers to environmentally sustainable computing or IT.
- The study and practice of designing, manufacturing, using, and disposing of computers, servers, and associated subsystems—such as monitors, printers, storage devices, and networking and communications systems—efficiently and effectively with minimal or no impact on the environment.

2. Green Computing Architecture



Architecture

- Overview of Green Computing Architecture
- Power Consumption in Laptop
- The Goals of Green Computing
- Impact of Green Computing Architecture
- Metrics of Green Computing Architecture
- Solution of Green Computing Architecture

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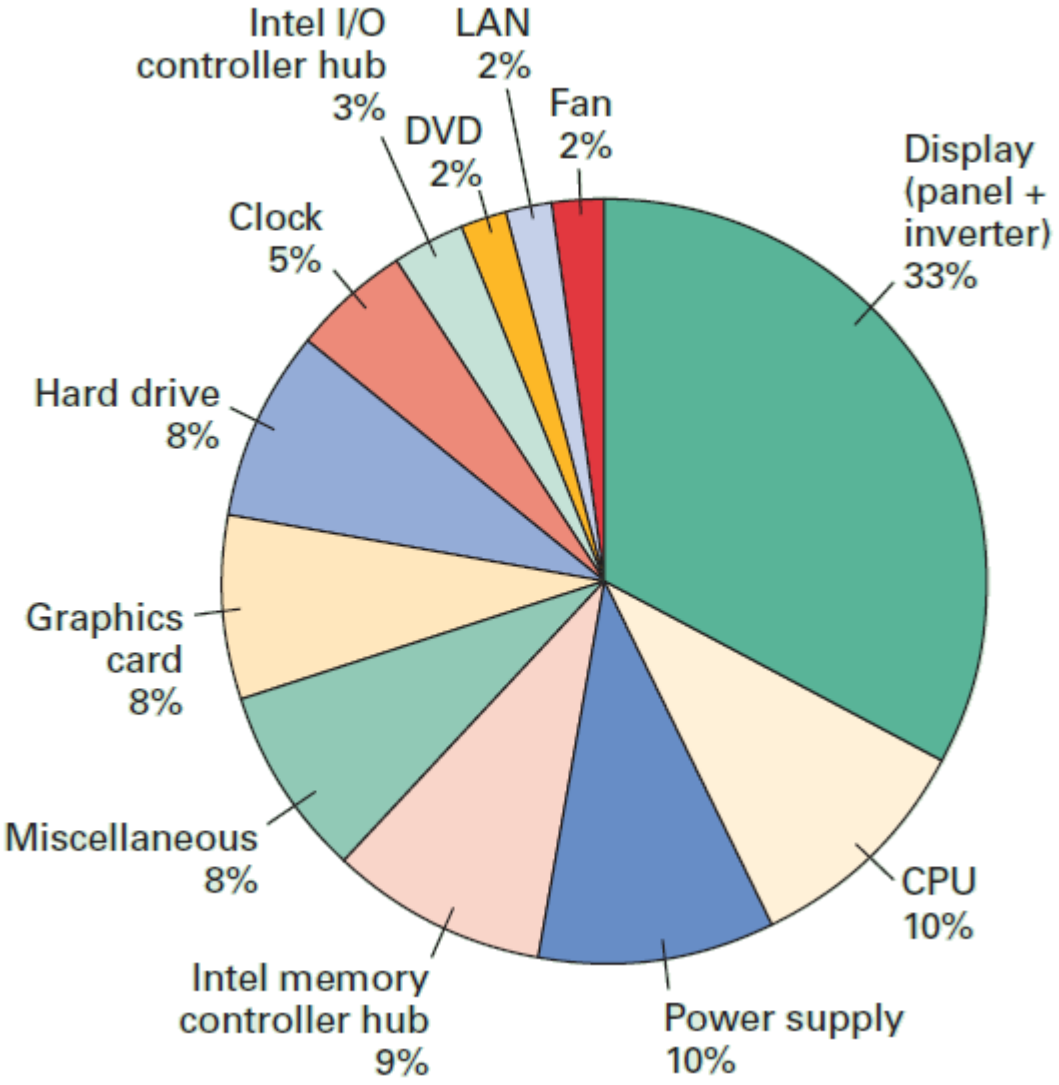
Overview of Green Computing Architecture

- The statistic results of the power consumption of each components of a laptop computer is shown first. With the statistic results of power consumption, we can realized which component consumes more power and can try to reduce the power consumption of these components.
- The second part shows the ecosystem view of green computing architecture, which contains impact, metrics, and solutions of green computing.

Power Consumption in An Average Laptop



"GREEN COMPUTING", Department of the Premier, GJPB Willemse, www.fs.gov.za

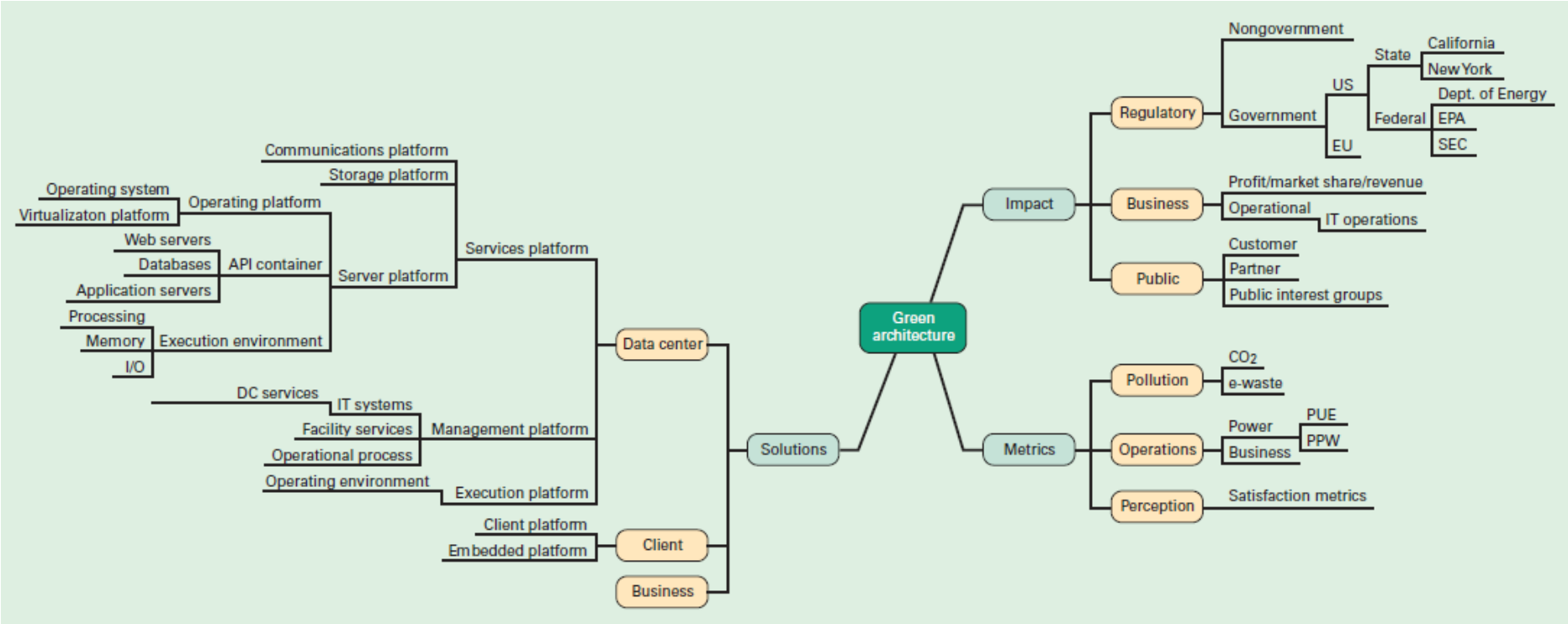
Power Consumption in An Average Laptop (cont.)

- The powerful new laptop with the terrifically beautiful video display might require a more expensive battery technology if the laptop's weight is to be maintained as well as its battery life.
- Longer battery life always comes with a price—typically a guns-or-butter trade-off between heavier batteries or more expensive battery technologies for every additional minute of battery life.

The Goals of Green Computing

- The goals of green computing are similar to green chemistry; reduce the use of hazardous materials, maximize energy efficiency during the product's lifetime, and promote the recyclability or biodegradability of defunct products and factory waste.
- Research continues into key areas such as making the use of computers as energy-efficient as possible, and designing algorithms and systems for efficiency-related computer technologies.

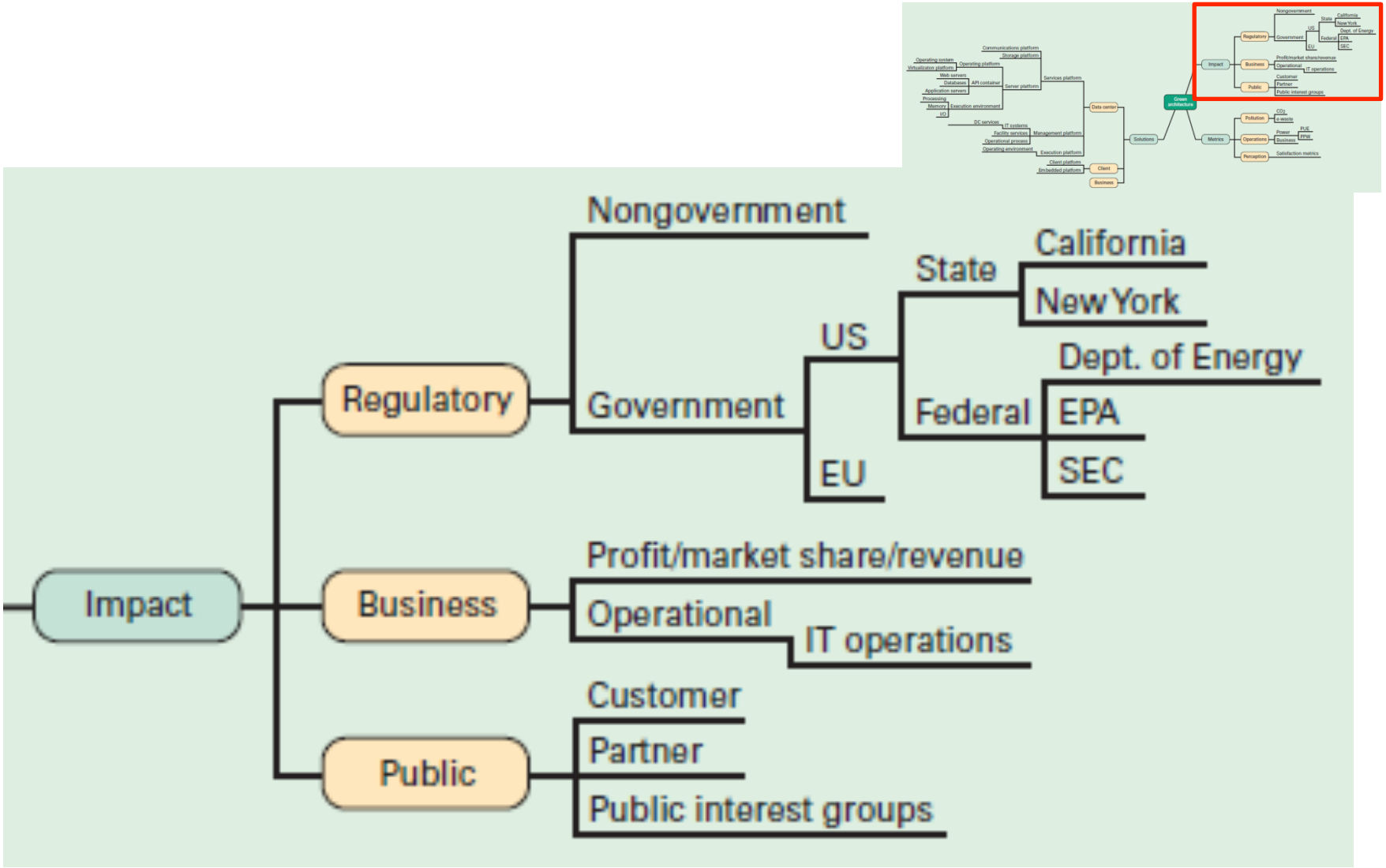
An Ecosystem is a View of Green Computing's Architectural



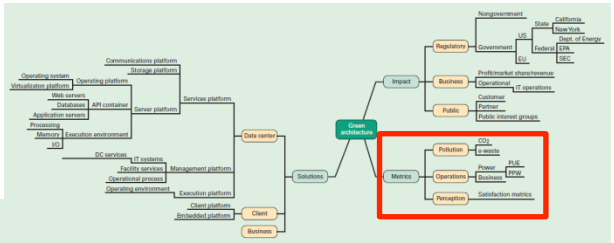
Green Computing's Architecture

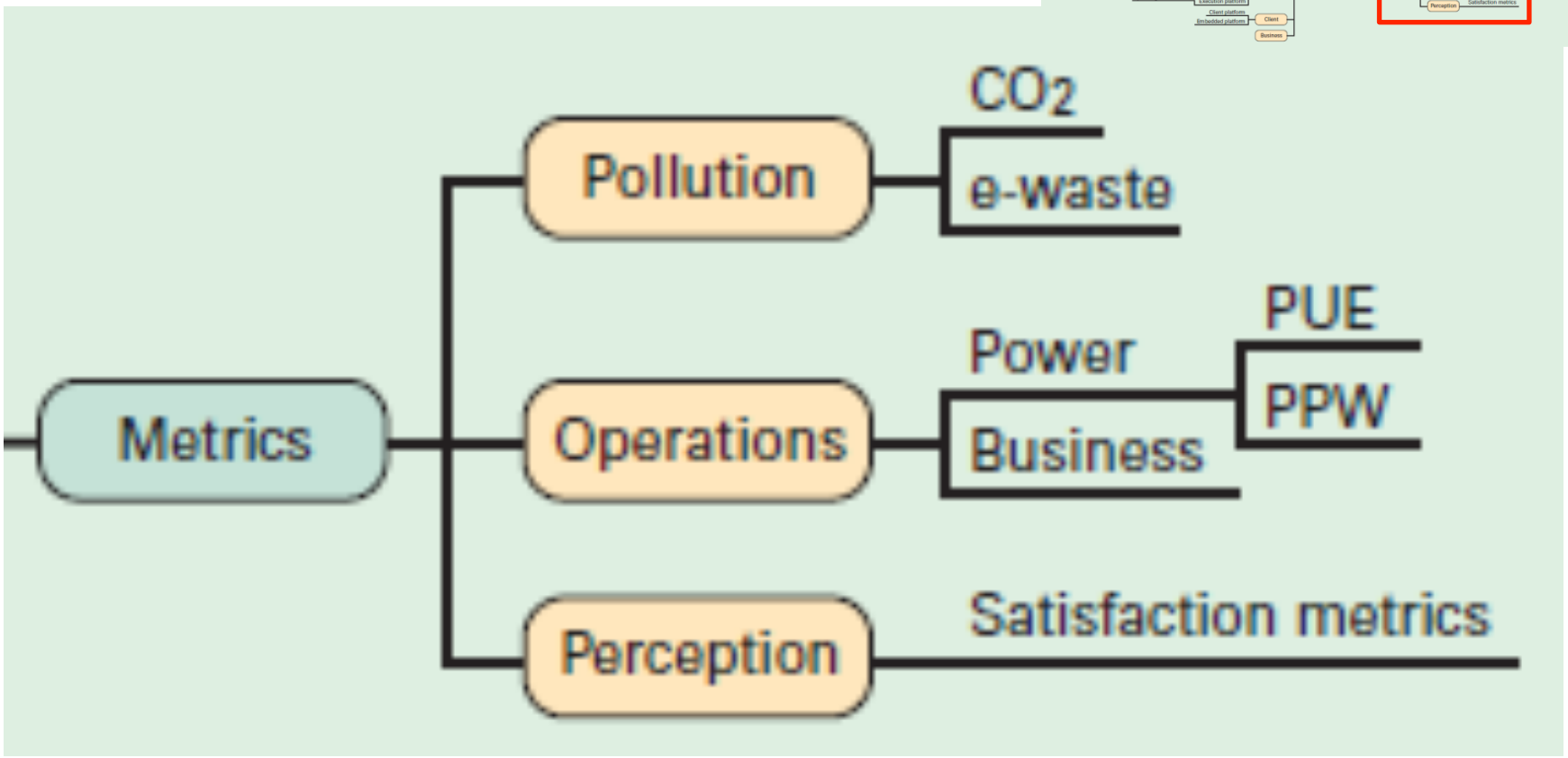
- In a large IT operation, this tree could conceivably span hundreds if not thousands of branches, particularly if it includes multiple business units and data centers located around the world.
- There is also a clearer view of how deeply the architecture for green computing cuts across so many functional roles in an IT operation.

Impact of Green Computing

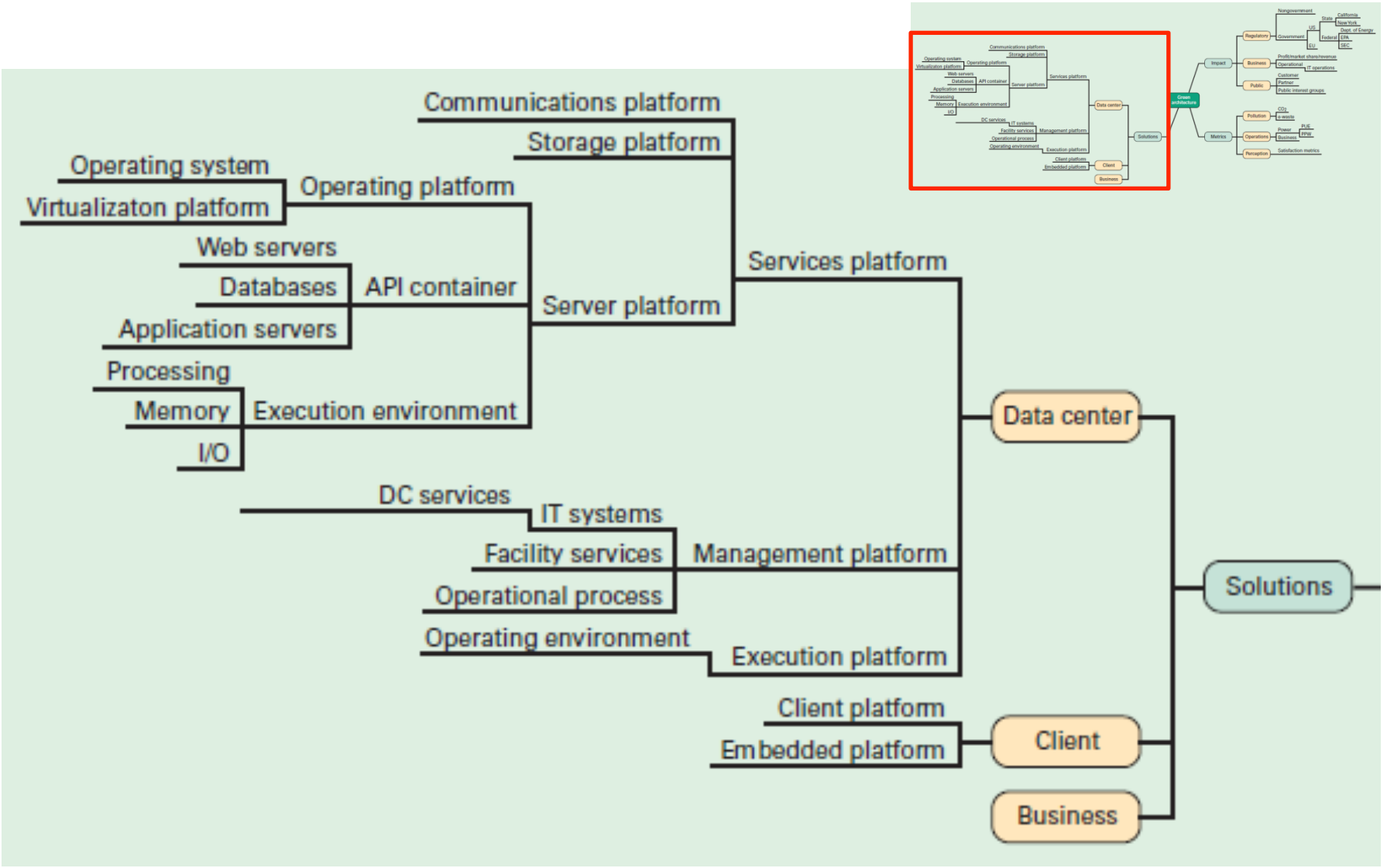


Metrics of Green Computing





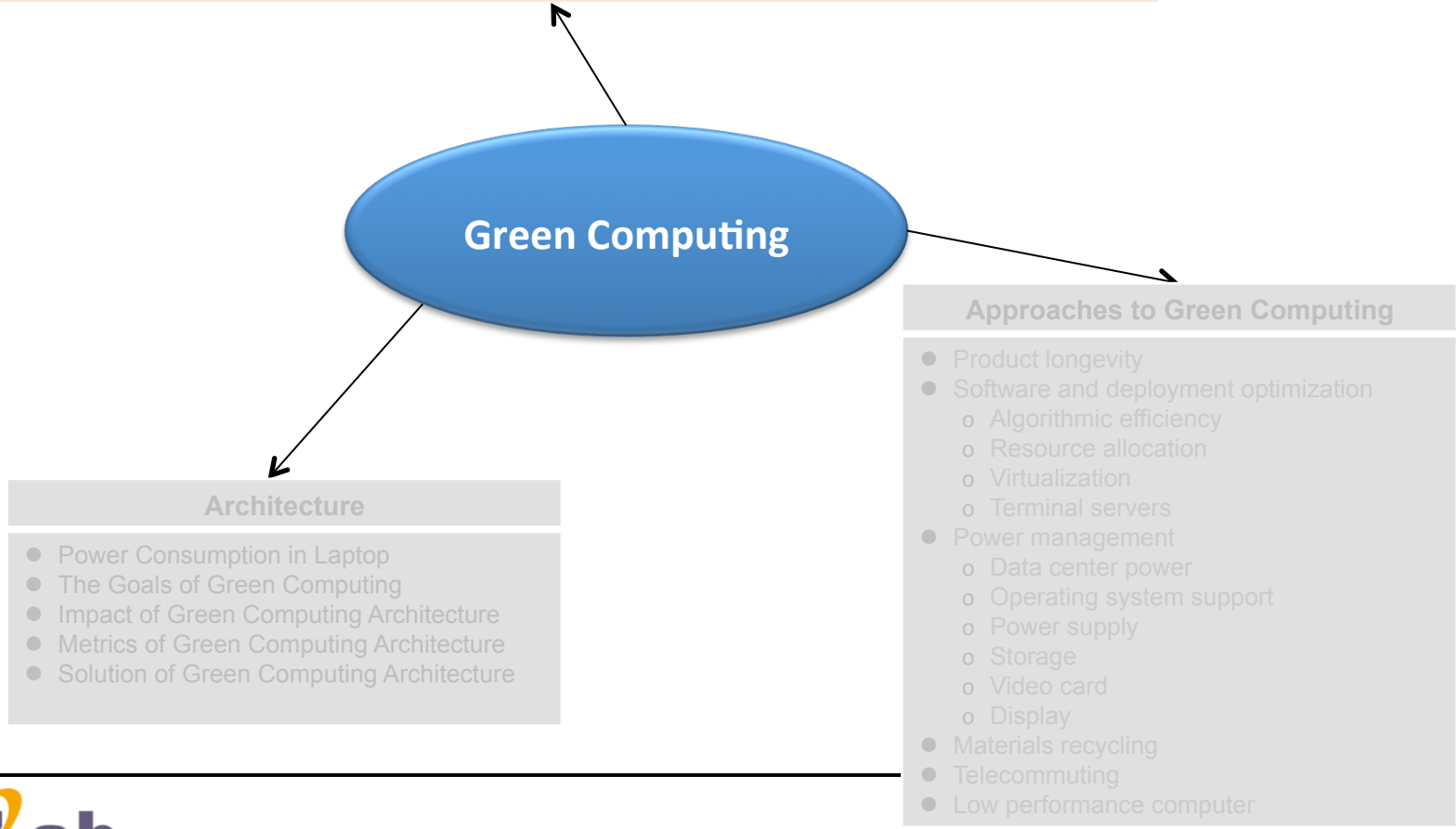
Solutions Green Computing



3. Regulations and Industry Initiatives

Regulations and industry initiatives

- Government
- Industry



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Overview of Regulations and Industry Initiatives

- The Organization for Economic Co-operation and Development (OECD) has published a survey of over 90 government and industry initiatives on "Green ICTs", i.e. information and communication technologies, the environment and climate change.
- Initiatives tend to concentrate on the greening ICTs themselves rather than on their actual implementation to tackle global warming and environmental degradation.
- Only 20% of initiatives have measurable targets, with government programs tending to include targets more frequently than business associations.

Regulations and Industry Initiatives - Government

- Many governmental agencies abroad have continued to implement standards and regulations that encourage green computing.
- The Energy Star program was revised in October 2006 to include stricter efficiency requirements for computer equipment, along with a tiered ranking system for approved products.
- In 2008, a report published in the UK by the Department for Communities and Local Government, quantified that the potential carbon savings from increasing the usage of online public service delivery were significantly in excess of the negative impact of extra IT server capacity.

[1] WIKIPEDIA, http://en.wikipedia.org/wiki/Main_Page

The American Recovery and Reinvestment Act

- There are currently 26 US states that have established state -wide recycling programs for obsolete computers and consumer electronics equipment.
- In 2010, the American Recovery and Reinvestment Act (ARRA) was signed into legislation by President Obama.
- The bill allocated over $90 billion to be invested in green initiatives (renewable energy, smart grids, energy efficiency, etc.)
- In January 2010, the U.S. Energy Department granted $47 million of the ARRA money towards projects that aim to improve the energy efficiency of data centers.
- The projects will provide research on the following three areas: optimize data center hardware and software, improve power supply chain, and data center cooling technologies.

Energy Star

- Energy Star is an international standard for energy efficient consumer products originated in the United States of America.
- It was first created as a United States government program during the early 1990s, but Australia, Canada, Japan, New Zealand, Taiwan and the European Union have also adopted the program.
- Devices carrying the Energy Star logo, such as computer products and peripherals, kitchen appliances, buildings and other products, generally use 20%–30% less energy than required by federal standards.

Energy Star specifications

- Energy Star specifications differ with each item, and are set by either the Environmental Protection Agency or the Department of Energy. The following highlights product and specification information available on the Energy Star website.
- Energy Star items:
  - Computers
  - Servers
  - Appliances
  - Heating and cooling systems
  - Home electronics
  - Imaging equipment

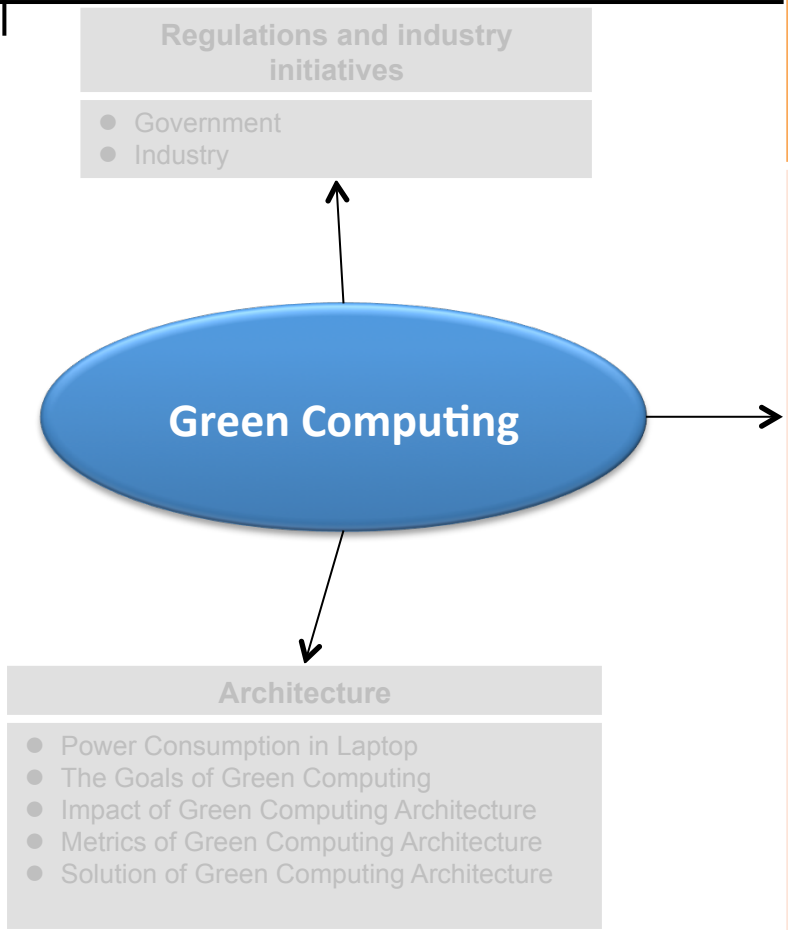
Regulations and Industry Initiatives - Industry

- Industry
  - The Green Grid is a global consortium dedicated to advancing energy efficiency in data centers and business computing ecosystems.
  - Climate Savers Computing Initiative (CSCI) is an effort to reduce the electric power consumption of PCs in active and inactive states.
  - The CSCI provides a catalog of green products from it ‘s member organizations, and information for reducing PC power consumption.

The Green Grid

- The Green Grid is a non-profit, open industry consortium of end-users, policy-makers, technology providers, facility architects, and utility companies collaborating to improve the resource efficiency of data centers and business computing ecosystems.
- With more than 170 member companies around the world, The Green Grid seeks to unite global industry efforts, create a common set of metrics, and develop technical resources and educational tools to further its goals.

4. Approaches to Green Computing



Approaches to Green Computing

- Product longevity
- Software and deployment optimization
  - Algorithmic efficiency
  - Resource allocation
  - Virtualization
  - Terminal servers
- Power management
  - Data center power
  - Operating system support
  - Power supply
  - Storage
  - Video card
  - Display
- Materials recycling
- Telecommuting
- Low performance computer

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Overview of Approaches to Green Computing

- Modern IT systems rely upon a complicated mix of people, networks and hardware; as such, a green computing initiative must cover all of these areas as well. A solution may also need to address end user satisfaction, management restructuring, regulatory compliance, and return on investment (ROI).
- There are also considerable fiscal motivations for companies to take control of their own power consumption; of the power management tools available, one of the most powerful may still be simple, plain, common sense.

Overview of Approaches to Green Computing (cont.)

- In *Harnessing Green IT: Principles and Practices*, San Murugesan defines the field of green computing as efficiently and effectively with minimal or no impact on the environment.
  - study and practice of designing
  - Manufacturing
  - Using
  - disposing of computers
  - Servers
  - Associated subsystems
    - Monitors
    - Printers
    - storage devices
    - Networking
    - communications systems

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Outline of Approaches to Green Computing (cont.)

- Materials recycling
- Telecommuting
- Low performance computer

Approaches to Green Computing

- Product longevity
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Product Longevity

- The PC manufacturing process accounts for 70 % of the natural resources used in the life cycle of a PC.
- Fujitsu released a Life Cycle Assessment (LCA) of a desktop that show that manufacturing and end of life accounts for the majority of this laptop ecological footprint.
- The biggest contribution to green computing usually is to prolong the equipment's lifetime.
- "Look for product longevity, including upgradability and modularity."
  - Manufacturing a new PC makes a far bigger ecological footprint than manufacturing a new RAM module to upgrade an existing one.

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Software and deployment optimization

- Optimize the software and deployment is an efficiency way for saving energy which include algorithmic efficiency, resource allocation, virtualization, terminal servers.
- The efficiency of software and deployment has an impact on the amount of computer resources required for any given computing function and there are many efficiency trade-offs in writing programs.

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Algorithmic Efficiency

- The average Google search released 7 grams of carbon dioxide (CO_2), however, Google disputes this figure, arguing instead that a typical search produces only 0.2 grams of CO_2.
- An independent study by GreenIT.fr demonstrate that Windows 7 + Office 2010 require 70 times more memory (RAM) than Windows 98 + Office 2000 to write exactly the same text or send exactly the same e-mail than 10 years ago.
- Fine-grained green computing refers to running a program efficiently and effectively via a subtle power control on each computing resources as CPU, memory, registers, peripherals, clock management, and power supply.

Algorithmic Efficiency

Before

```
Program HelloWorld_c
    print "Hello World\n"      → Activity
    low_power_mode()          → Turn into low power mode
```

After

```
Program HelloWorld _f
    activate(memory_bank)     → Wake up the memory and io
    activate(io)
    print  "Hello World\n"     → Activity
    deactivate(memory_bank)   → Memory and io turn into sleep mode
    deactivate(io)
    low_power_mode()          → Turn into low power mode
```


[4] Chia-Tien Dan Lo and Kai Qian, "Green Computing Methodology for Next Generation Computing Scientists", 2010 IEEE 34th Annual Computer Software and Applications Conference

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Resource Allocation

- Resource allocation is used to assign the available resources in an economic way.
- In project management, resource allocation is the scheduling of activities and the resources required by those activities while taking into consideration both the resource availability and the project time.
- There are two parts of the resource allocation:
  - Strategic planning
  - Resource leveling

Resource Allocation – Strategic Planning

- In strategic planning, resource allocation is a plan for using available resources, for example human resources, especially in the near term, to achieve goals for the future.
- It is the process of allocating resources among the various projects or business units.
- The strategic planning has two parts:
  - Firstly, there is the basic allocation decision and
  - Secondly there are contingency mechanisms.
- The basic allocation decision is the choice of which items to fund in the plan, and what level of funding it should receive, and which to leave unfunded: the resources are allocated to some items, not to others.

Resource Allocation – Resource Leveling

- The main objective is to smooth resources requirements by shifting slack jobs beyond periods of peak requirements.
- Some of the methods essentially replicate what a human scheduler would do if he had enough time; others make use of unusual devices or procedures designed especially for the computer. They of course depend for their success on the speed and capabilities of electronic computers.

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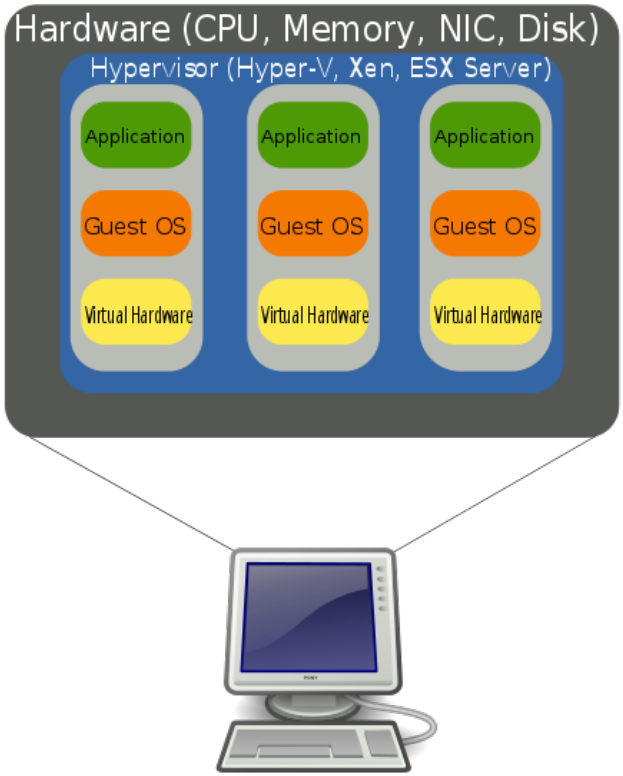
Virtualization

- Computer virtualization refers to the abstraction of computer resources, such as the process of running two or more logical computer systems on one set of physical hardware.
- With virtualization, a system administrator could combine several physical systems into virtual machines on one single, powerful system, thereby unplugging the original hardware and reducing power and cooling consumption.

Virtualization

- Full virtualization
  - In full virtualization, the virtual machine simulates enough hardware to allow an unmodified "guest" OS (one designed for the same instruction set) to be run in isolation.



Virtualization

- Hardware-assisted virtualization
  - In hardware-assisted virtualization, the hardware provides architectural support that facilitates building a virtual machine monitor and allows guest OSes to be run in isolation.
- Partial virtualization
  - In partial virtualization, including address space virtualization, the virtual machine simulates multiple instances of much of an underlying hardware environment, particularly address spaces.
  - Usually, this means that entire operating systems cannot run in the virtual machine – which would be the sign of full virtualization – but that many applications can run.

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Terminal Serves

- Terminal servers have also been used in green computing.
- When using the system, users at a terminal connect to a central server; all of the actual computing is done on the server, but the end user experiences the operating system on the terminal.
- These can be combined with thin clients, which use up to 1/8 the amount of energy of a normal workstation, resulting in a decrease of energy costs and consumption.
- There has been an increase in using terminal services with thin clients to create virtual labs.

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Power Management

- The Advanced Configuration and Power Interface (ACPI), an open industry standard, allows an operating system to directly control the power saving aspects of its underlying hardware.
- This allows a system to automatically turn off components such as monitors and hard drives after set periods of inactivity.
- Some programs allow the user to manually adjust the voltages supplied to the CPU, which reduces both the amount of heat produced and electricity consumed.

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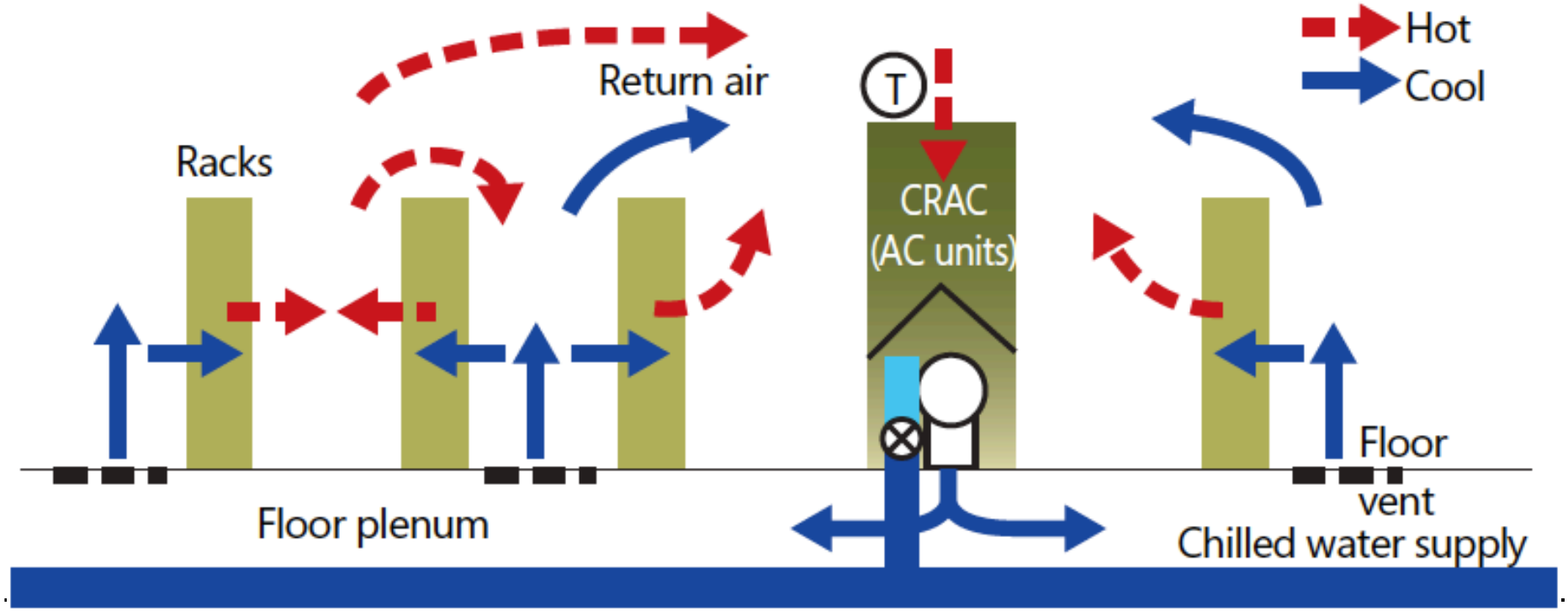
Data Center Power

- Data centers, which have been criticized for its extraordinary high energy demand, are a primary focus for proponents of green computing.
- The federal government has set a minimum 10% reduction target for data center energy usage by 2011.
- With the aid of a self-styled ultra efficient evaporative cooling technology, Google Inc. has been able to reduce its energy consumption to 50% of that of the industry average.

Data Center Power

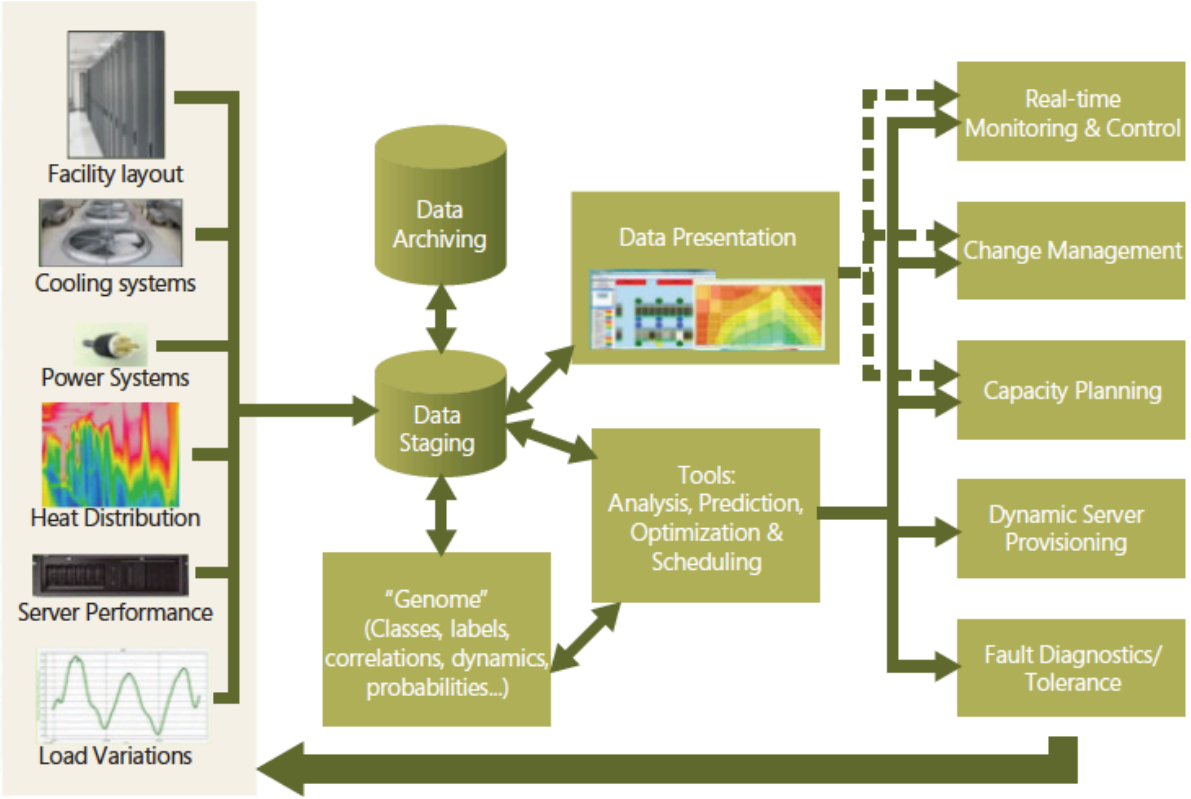
- An illustration of the cross section of a data center.
- Cold air is blown from floor vents, while hot air rises from hot aisles. Mixed air eventually returns to the CRAC where it is cooled with the help of chilled water, and the cycle repeats.



[3] Jie Liu, Feng Zhao, Jeff O'Reilly, Amaya Souarez, Michael Manos, Chieh-Jan Mike Liang, and Andreas Terzis, "Project Genome: Wireless Sensor Network for Data Center Cooling"

Data Center Power

- Data collected from physical and cyber systems in data centers is correlated and analyzed to provide models and tools for data center management and performance optimization.



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Operation System Support

- The dominant desktop operating system, Microsoft Windows, has included limited PC power management features since Windows 95. These initially provided for stand-by (suspend-to-RAM) and a monitor low power state.
- Windows 2000 was the first NT based operating system to include power management, his required major changes to the underlying operating system architecture and a new hardware driver model; it also introduced Group Policy, a technology which allowed administrators to centrally configure most Windows features.

Operation System Support

- The most recent release, Windows 7 retains these limitations but does include refinements for more efficient user of operating system timers, processor power management, and display panel brightness.
- The most significant change in Windows 7 is in the user experience.
- The prominence of the default High Performance power plan has been reduced with the aim of encouraging users to save power.

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Power Supply

- Desktop computer power supplies (PSUs) are generally 70 – 75% efficient, dissipating the remaining energy as heat.
- An industry initiative called 80 PLUS certifies PSUs that are at least 80% efficient; typically these models are drop-in replacements for older, less efficient PSUs of the same form factor.
- As of 20 July 2007, all new Energy Star 4.0-certified desktop PSUs must be at least 80% efficient.

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Storage

- Smaller form factor (e.g. 2.5 inch) hard disk drives often consume less power than physically larger drives.
- With no moving parts, power consumption may be reduced somewhat for low capacity flash based devices.
- As hard drive prices have fallen, storage farms have tended to increase in capacity to make more data available online, this includes archival and backup data that would formerly have been saved on tape or other offline storage.
- The increase in online storage has increased power consumption.
- Reducing the power consumed by large storage arrays, while still providing the benefits of online storage, is a subject of ongoing research.

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Video Card

- A fast GPU may be the largest power consumer in a computer.
- Energy efficient display options include:
  - No video card - use a shared terminal, shared thin client, or desktop sharing software if display required.
  - Use motherboard video output - typically low 3D performance and low power.
- Select a GPU based on low idle power, average wattage or performance per watt.

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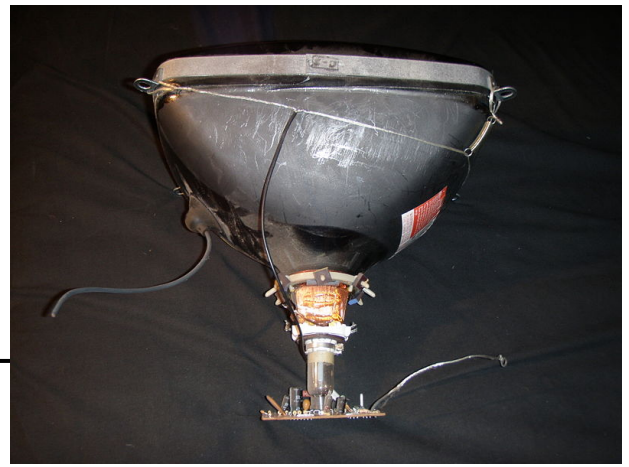
Display

- CRT monitors typically use more power than LCD monitors, they also contain significant amounts of lead.
- LCD monitors typically use a cold-cathode fluorescent bulb to provide light for the display.
- Some newer displays use an array of light-emitting diodes (LEDs) in place of the fluorescent bulb, which reduces the amount of electricity used by the display.

Cathode ray tube (CRT)

- The first computer monitors used cathode ray tubes (CRT).
- Until the early 1980s, they were known as video display terminals and were physically attached to the computer and keyboard.
- CRT remained the standard for computer monitors through the 1990s.
- CRT technology remained dominant in the PC monitor market into the new millennium partly because it was cheaper to produce and offered viewing angles close to 180 degrees.

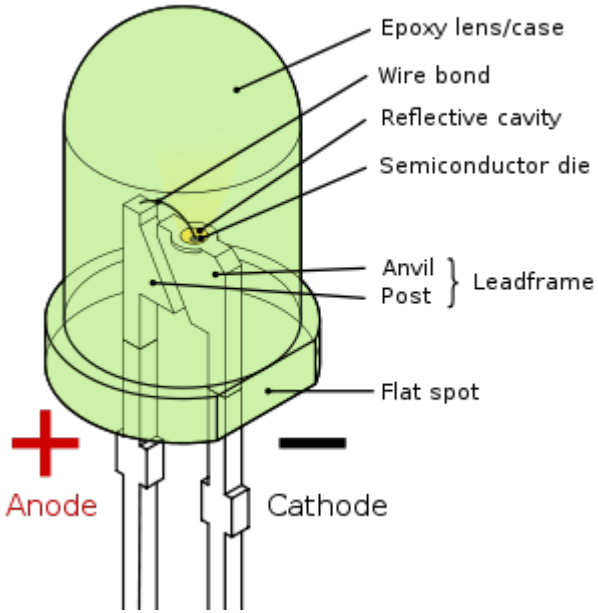


Liquid Crystal Display

- A **liquid crystal display** (**LCD**) is a flat panel display, electronic visual display, or video display that uses the light modulating properties of liquid crystals (LCs). LCs do not emit light directly.
- LCDs are more energy efficient and offer safer disposal than CRTs.
- Its low electrical power consumption enables it to be used in battery-powered electronic equipment.
- It is an electronically modulated optical device made up of any number of segments filled with liquid crystals and arrayed in front of a light source or reflector to produce images in color or monochrome.
- The most flexible ones use an array of small pixels.

Light-emitting diode

- A light-emitting diode (LED) is a semiconductor light source.
- LEDs are used as indicator lamps in many devices and are increasingly used for other lighting.
- Early LEDs emitted low-intensity red light, but modern versions are available across the visible, ultraviolet, and infrared wavelengths, with very high brightness.



Organic light-emitting diode

- Organic light-emitting diode (OLED) monitors provide higher contrast and better viewing angles than LCDs, and are predicted to replace them.
- In 2011 a 25 inch OLED monitor costs $6000, but the prices are expected to drop.
- LEDs are often small in area (less than 1 mm2), and integrated optical components may be used to shape its radiation pattern.
- LEDs present many advantages over incandescent light sources including lower energy consumption, longer lifetime, improved robustness, smaller size, and faster switching.
- LEDs powerful enough for room lighting are relatively expensive and require more precise current and heat management than compact fluorescent lamp sources of comparable output.

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Materials Recycling

- Computer systems that have outlived their particular function can be repurposed, or donated to various charities and non-profit organizations.
- Recycling computing equipment can keep harmful materials such as lead, mercury, and hexavalent chromium out of landfills, but often computers gathered through recycling drives are shipped to developing countries where environmental standards are less strict than in North America and Europe.

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Telecommuting

- Teleconferencing and telepresence technologies are often implemented in green computing initiatives.
- The advantages are many; increased worker satisfaction, reduction of greenhouse gas emissions related to travel, and increased profit margins as a result of lower overhead costs for office space, heat, lighting, etc.
- The savings are significant; the average annual energy consumption for U.S. office buildings is over 23 kilowatt hours per square foot, with heat, air conditioning and lighting accounting for 70% of all energy consumed.

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- Low performance computer

Low Performance Computers

- As of 2007, several personal computer vendors (e.g., Everex, Linutop, Systemax, Zonbu and OLPC) ship dedicated low-power PCs.
- These systems provide minimal hardware peripherals and low performance processors, which makes them impractical for applications that require a lot of processing power such as computer gaming and video production.
- A low power PCs is usually much smaller than traditional desktop. The limited capacity for upgrades, low performance and proprietary may lead to shorter life spans and greater difficulty in repair.

Outline

1. Abstract
2. Green computing architecture
3. Regulations and industry initiatives
4. Approaches to green computing
5. Conclusion
6. Reference

5. Conclusion

- 在ICT產業邁向green computing的過程中，藉由從外部的材料、硬體方面改善，到軟體執行的最佳化與改進，這些技術包含延長產品的生命週期、軟體與設備的最佳化、能源管理方法、廢棄材料回收、遠距離通訊.....等等技術，透過這些技術，不但可以讓設備或是系統擁有高效率的處理與執行，更可以減少產生的廢棄物與溫室氣體，不但能增加產品的使用率，也可以避免環境的汙染，讓整個地球生態能夠更好。

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1) WIKIPEDIA, http://en.wikipedia.org/wiki/Main_Page
2) "GREEN COMPUTING", Department of the Premier, GJPB Willemse, www.fs.gov.za
3) Jie Liu, Feng Zhao, Jeff O'Reilly, Amaya Souarez, Michael Manos, Chieh-Jan Mike Liang, and Andreas Terzis, "Project Genome: Wireless Sensor Network for Data Center Cooling"
4) Chia-Tien Dan Lo and Kai Qian, "Green Computing Methodology for Next Generation Computing Scientists", 2010 IEEE 34th Annual Computer Software and Applications Conference
5) Joseph Williams and Lewis Curtis, "Green: The New Computing Coat of Arms?"
6) David Wang, "Meeting Green Computing Challenges", 2007 IEEE

Homework #11:

1. What is the Energy Star and its major activity ?
2. List five approaches to green computing and explain one of the five approaches in detail.
3. Explain the methods for software and deployment optimization.