Green Computing

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What is Green Computing?

- Greening of computing
  - Sustainable IT
  - How to design energy-efficient hardware, software and systems?
- Computing for Greening
  - Use of IT to make physical infrastructure efficient?
    - Homes, offices, buildings, transportation

Some History

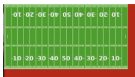
- Energy-efficient mobile devices a long standing problem
  - Motivation: better battery life, not green
- Recent growth of data centers
  - More energy-efficient server design
  - Motivation: lower electricity bills
    - Green systems, lower carbon footprint

Computing and Power Consumption

- Energy to Compute
  - 20% power usage in office buildings
  - 50%-80% at a large college
  - 3% of our carbon footprint and growing
- Data centers are a large fraction of the IT carbon footprint
  - PCs, mobile devices also a significant part

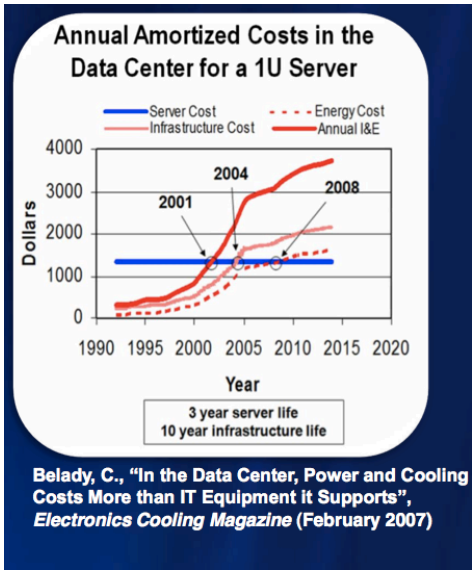
What is a data center?

- Facility for housing a large number of servers and data storage
- Google data center (Dalles, OR)
  - 12 football fields in size
    - Compare to box stores!
  - 100 MW of power
    - Enough for a small city
  - ~ 100K servers



Each data center is
11.5 times
the size of a football field

Data Center Energy Costs



Belady, C., "In the Data Center, Power and Cooling Costs More than IT Equipment it Supports", *Electronics Cooling Magazine* (February 2007)

Energy Bill of a Google Data center

- Assume 100,000 servers
- Monthly cost of 1 server
  - 500W server
  - Cost=(Watts X Hours / 1000) * cost per KWH
  - Always-on server monthly cost = $50
- Monthly bill for 100K servers = $5M
- What about cost of cooling?
  - Use PUE (power usage efficiency)
  - PUE =2 => cost doubles
  - Google PUE of 1.2 => 20% extra on 5M (~ $6M)

Class exercises

- Calculate the energy cost and carbon footprint of
  - A laptop
  - A desktop
  - Always-on machine
  - A machine that is switched off in the night

How to design green data centers?

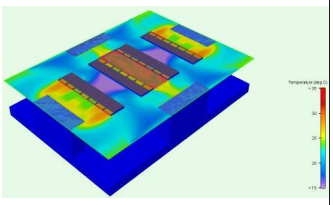
- A green data center will
  - Reduce the cost of running servers
  - Cut cooling costs
  - Employ green best practices for infrastructure

Reducing server energy cost

- Buy / design energy-efficient servers
  - Better hardware, better power supplies
  - DC is more energy-efficient than AC
- Manage your servers better!
  - Intelligent power management
  - Turn off servers when not in use
  - Virtualization => can move apps around

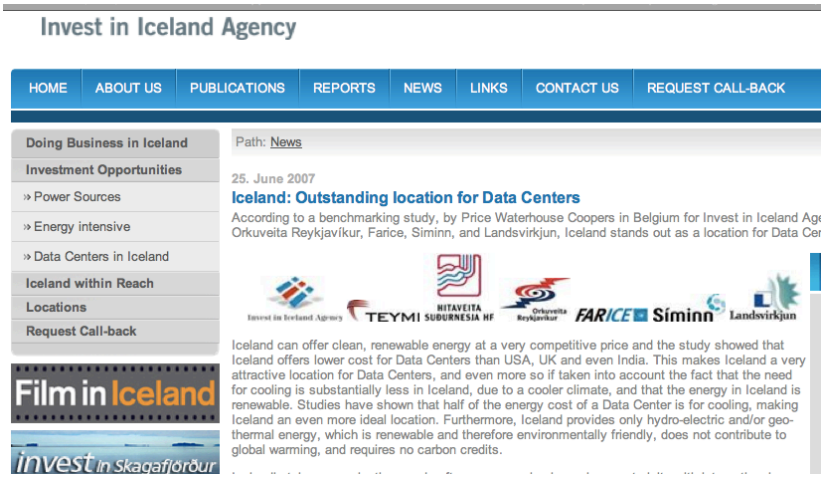
Reducing cooling costs

- Better air conditioning
  - Thermal engineering / better airflow
  - Move work to cooler regions



- Newer cooling
  - Naturally cooled data ctrs
  - Underground bunkers

Build them in Iceland



Desktop Power management

- Large companies => 50K desktops or more
  - Always on: no one switches them off at night
  - Night IT tasks: backups, patches etc
- Better desktop power management
  - Automatic sleep policies
  - Automatic / easy wakeups [see Usenix 2010]

IT for Greening

- How can we use IT to make buildings green?
  - Use sensors, smart software, smart appliances, smart meters …..

Potential Solution

- Monitor and profile usage
  - Power supply/demand profile
- Increase Efficiency
  - Turn on/off systems automatically
  - Consolidate computers
  - Tune various subsystems
- Use Alternative Energy Sources
  - Tune systems to variable energy supplies

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Fine-grained Building Monitoring

- Designed sensors for power outlet monitoring
  - Based on the Kill-A-Watt design

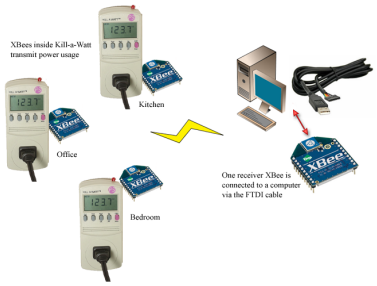
- Modified sensor with low-power wireless radio
  - Transmits data to strategically placed receivers
  - Use plug computers for receivers

Fine-grained Building Monitoring

- Advantages
  - Accurate, fine-grain data
  - Cheap money-wise to build
  - Able to put them everywhere
  - Good experience for undergraduates

- Disadvantage
  - Expensive time-wise to build

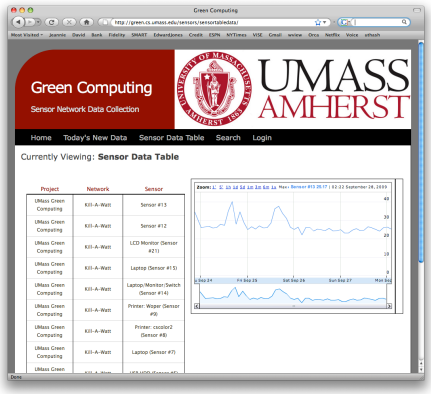
Tweet-a-watt Project



http://www.ladyada.net/make/tweetawatt/
Or just google for tweetawatt

Umass Green computing

- http://green.cs.umass.edu
  - 50+ sensors to monitor PC, printers, kitchen …
  - Web application for viewing or querying data

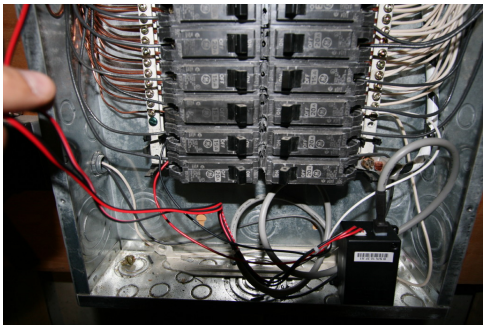


Meter-level Monitoring

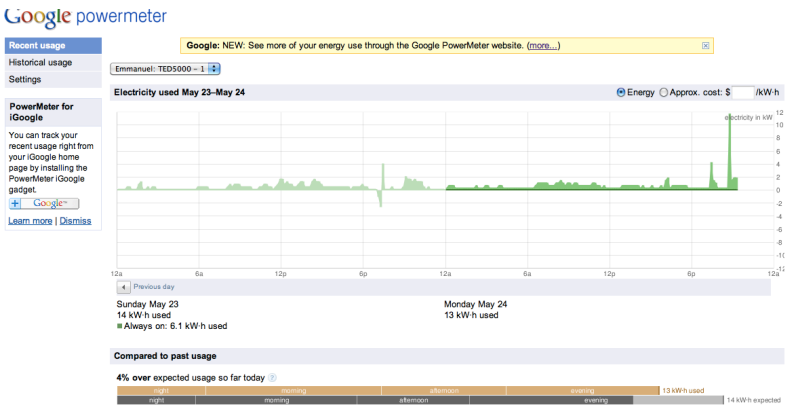
- Many off-the-shelf products available
  - TED – The Energy Detective
  - Blue Line PowerCost Monitor

TED Meter Monitoring

- Install on main panel



View on Google Powermeter



Blue Line Powercost Monitor

- Install on electricity meter (no wiring)
  - Easier to install but not Internet-enabled

Energy Harvesting Deployment

- Collect data on wind and solar energy harvesting
  - How can we use solar panels and wind turbines in Western Mass. to power IT?
  - Is the harvesting predictable?
- Study the best way to use energy to power compute clusters
  - Utility-scale energy-harvesting data centers are already coming online
  - We are looking at smaller scale

Energy Harvesting Deployment

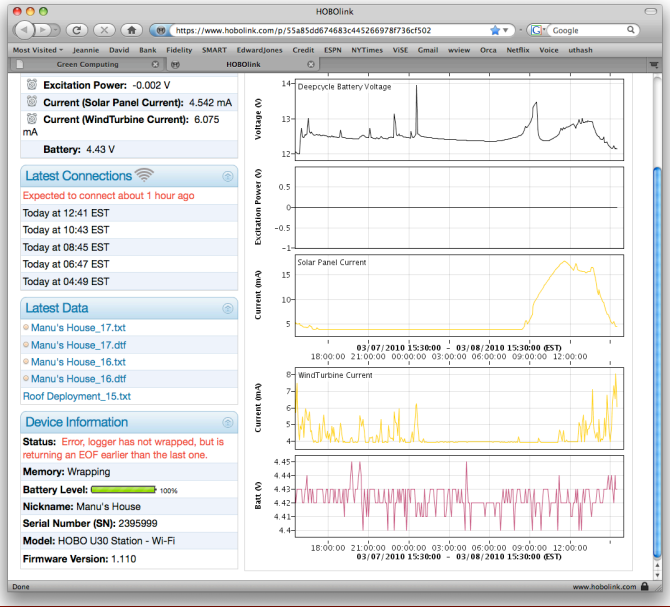
- Deployed multiple 400 watt wind turbines and 65 watt solar panels
- Use Hobo Data Logger to automatically upload data for archiving and viewing

Deployments in Western MA

Energy Harvesting in Winter

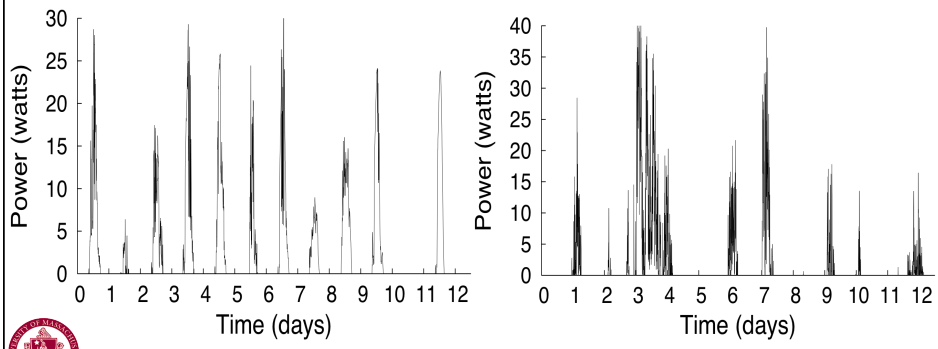
Winters are very challenging for solar deployments in New England

Energy Harvesting Deployment



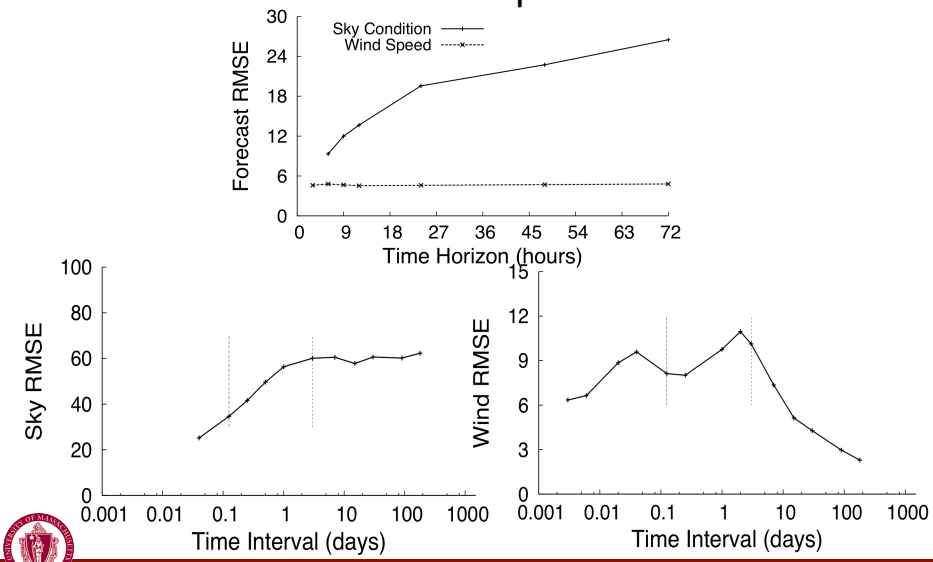
Analyzing Forecast Data

- Harvesting is highly variable
  - Both wind and solar in Amherst, MA are variable
  - NWS data reveals high variability in other regions too



Analyzing Forecast Data

- Forecasts are better for prediction than the Past



Summary

- Greening of computing
  - Design of energy-efficient hardware & software
- Computing for greening
  - Use of IT for monitoring
  - Use of intelligent software for power management
  - Forecasting for renewable energy harvesting