

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



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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



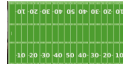
Computing and Power Consumption

- 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?

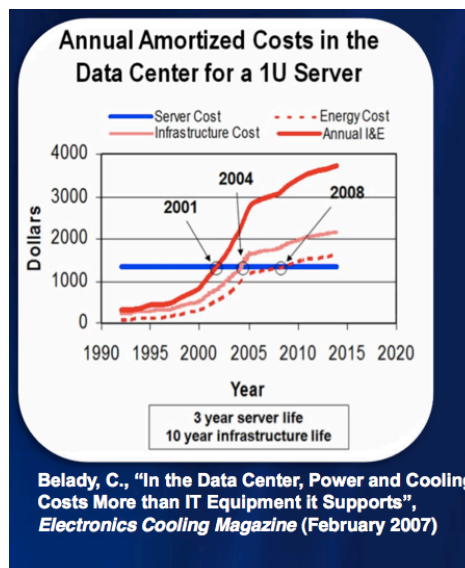
- Facility for housing a large number of servers and data storage
- Google data center (Dalles, OR)
 - 12 football fields in size
 - Compare to box stores!
 - 100 MW of power
 - Enough for a small city
 - ~ 100K servers



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



Data Center Energy Costs



Energy Bill of a Google Data center

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



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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



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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



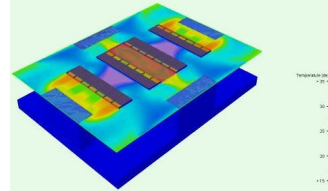
Reducing server energy cost

- 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

Invest in Iceland Agency

HOME	ABOUT US	PUBLICATIONS	REPORTS	NEWS	LINKS	CONTACT US	REQUEST CALL-BACK
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Doing Business in Iceland Path: [News](#)

Investment Opportunities 25. June 2007

» Power Sources **Iceland: Outstanding location for Data Centers**

» Energy intensive According to a benchmarking study, by Price Waterhouse Coopers in Belgium for Invest in Iceland Agency, Orkuveita Reykjavíkur, Farice, Siminn, and Landsvirkjun, Iceland stands out as a location for Data Centers

» Data Centers in Iceland

Iceland within Reach

Locations

Request Call-back

Iceland can offer clean, renewable energy at a very competitive price and the study showed that Iceland offers lower cost for Data Centers than USA, UK and even India. This makes Iceland a very attractive location for Data Centers, and even more so if taken into account the fact that the need for cooling is substantially less in Iceland, due to a cooler climate, and that the energy in Iceland is renewable. Studies have shown that half of the energy cost of a Data Center is for cooling, making Iceland an even more ideal location. Furthermore, Iceland provides only hydro-electric and/or geo-thermal energy, which is renewable and therefore environmentally friendly, does not contribute to global warming, and requires no carbon credits.

Film in Iceland

invest in Skagaförður



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



Potential Solution

- **Monitor and profile usage**
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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



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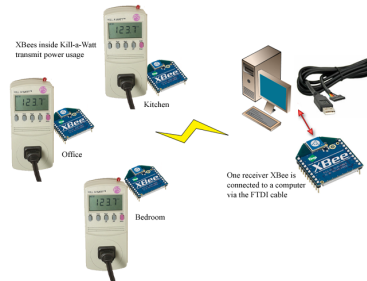
Fine-grained Building Monitoring

- 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



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Tweet-a-watt Project



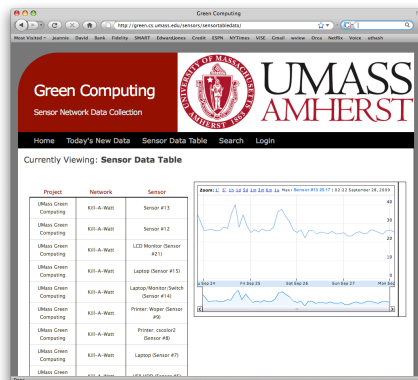
<http://www.ladyada.net/make/tweetawatt/>
Or just google for tweetawatt



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Umass Green computing

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



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Meter-level Monitoring

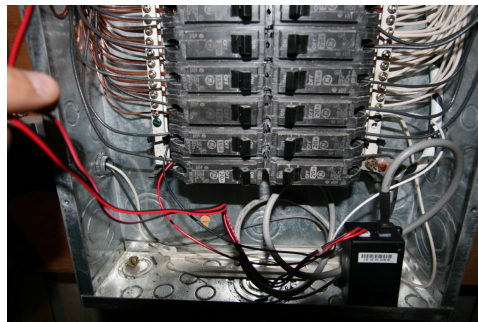
- Many off-the-shelf products available
 - TED - The Energy Detective
 - Blue Line PowerCost Monitor



TED Meter Monitoring

- Install on main panel

TED 5000-G™



View on Google Powermeter



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Blue Line Powercost Monitor

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



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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



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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



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Deployments in Western MA



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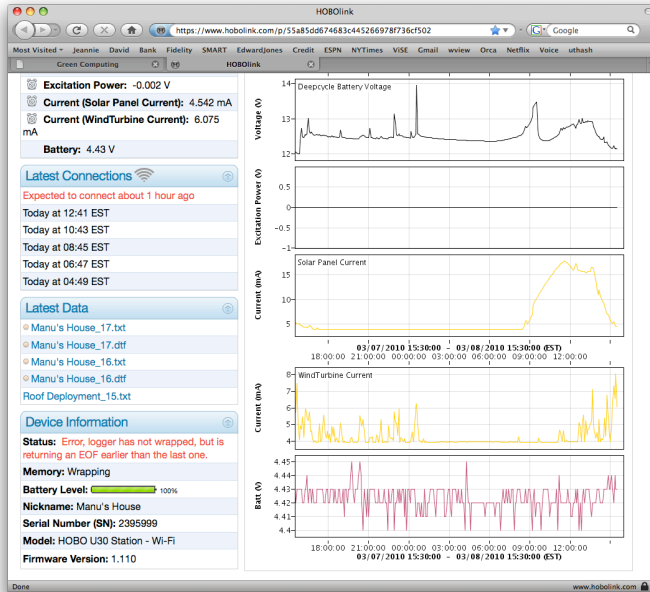
Energy Harvesting in Winter

Winters are very challenging for solar deployments in New England



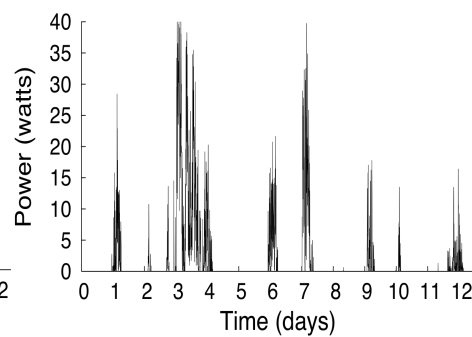
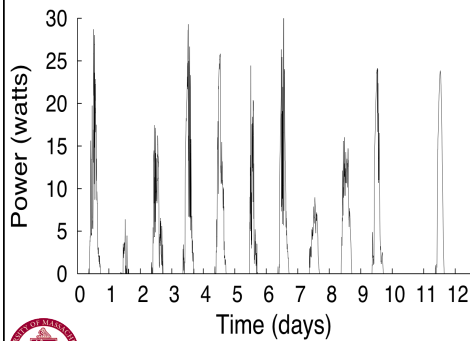
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Energy Harvesting Deployment



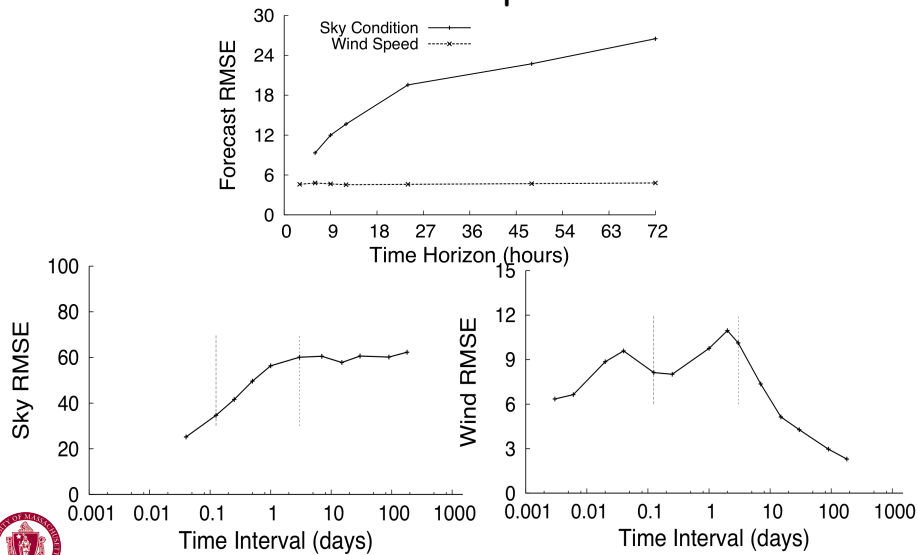
Analyzing Forecast Data

- 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

