Sustainability in Microelectronics

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PIRL Product Innovation Research Lab

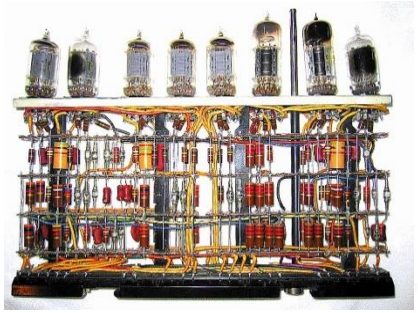
Transformation to Microelectronics

Progress the past half century:

- 1950's Vacuum tube computers filled entire rooms; Texas Instruments released the first silicone transistor in 1954 [1]
- 1960's Transistors replaced vacuum tubes; # of transistors on a micro chip doubles from 32 to 64; Gordon Moore predicts the number will increase to 65,000 by 1975. [2]
- 1970's Integrated circuit boards with hundreds of transistors; Moore revises his forecast pace- chips to double every two years; i.e. Moore's law.
- 1980's Chips containing millions of transistors
- 1990's Internet connected hundreds of millions of computers
- 2000's Ubiquitous computing- chips everywhere; designed into the environment- furniture, appliances, pictures, walls, cars, clothes all talking to one another. [3]

1. Moore, G.E. (1975) Progress in digital integrated electronics, Technical Digest, IEEE International Electronic Devices Meeting, pp. 11-13.
2. Smil, Vaclav (2014) *Making the Modern World,* John Wiled and Sons, Ltd, p. 72
3. .Kaku, Michio (2011) *Physics of the Future,* Random House, p. 26

1950's



IBM computer early vacuum tube
http://www.chipsetc.com

Progress the past half century:

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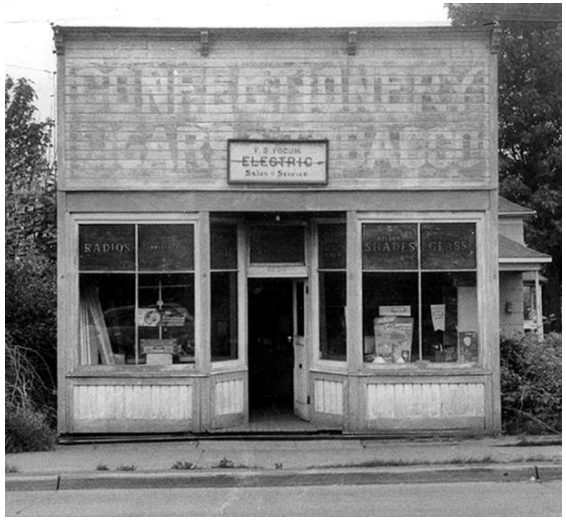

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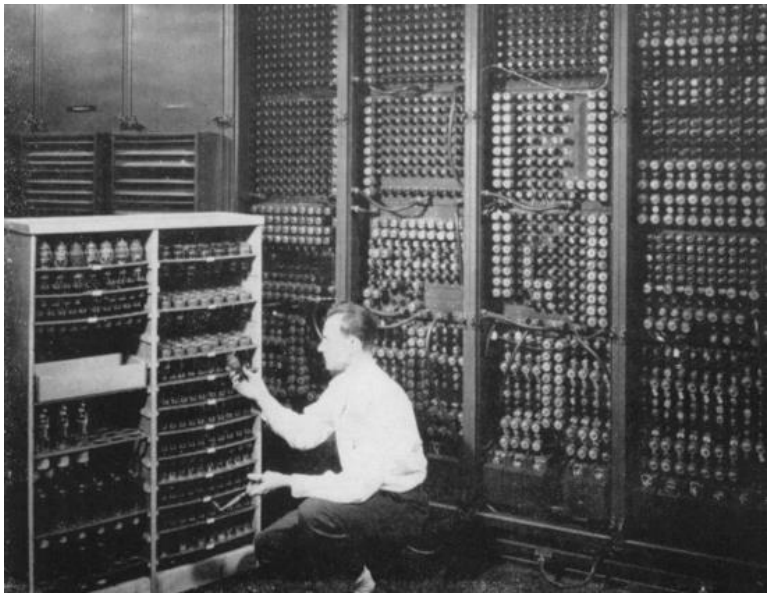
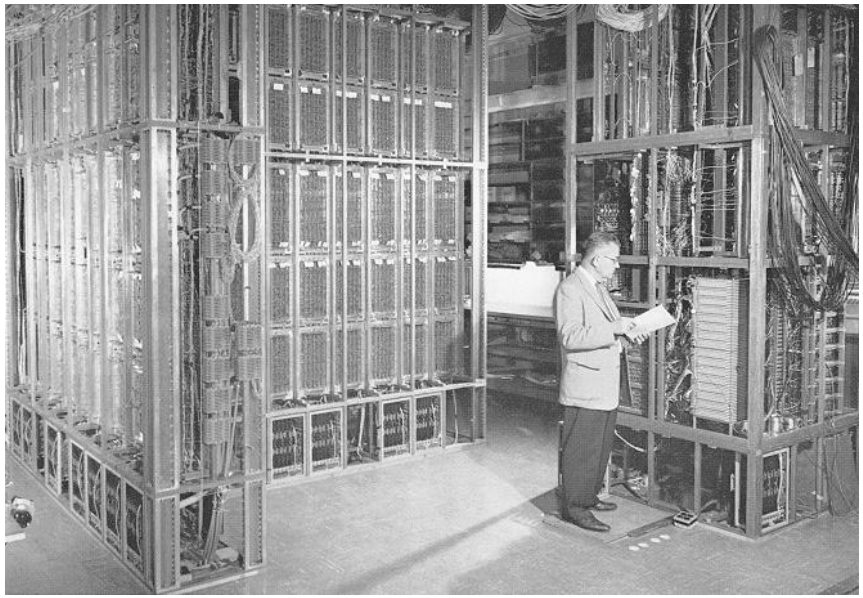


ENIAC Electronic Numerical integrator and Calculator



ILLIAC Electronic Numerical integrator and Calculator
University of Illinois at Urbana-Champaign

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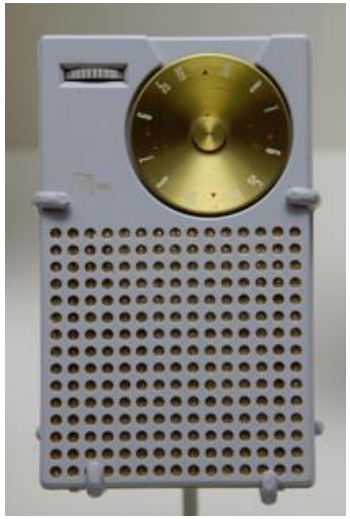

http://www.ericwrobbel.com/collections/transistor-radios-a.jpg

2 Smil, Vaclav (2014) *Making the Modern World,* John Wiled and Sons, Ltd, p. 72

1960's

1966 Mercury contamination of
Minamata Bay and Shirauni Sea, Japan

Horrible birth defects

1970's

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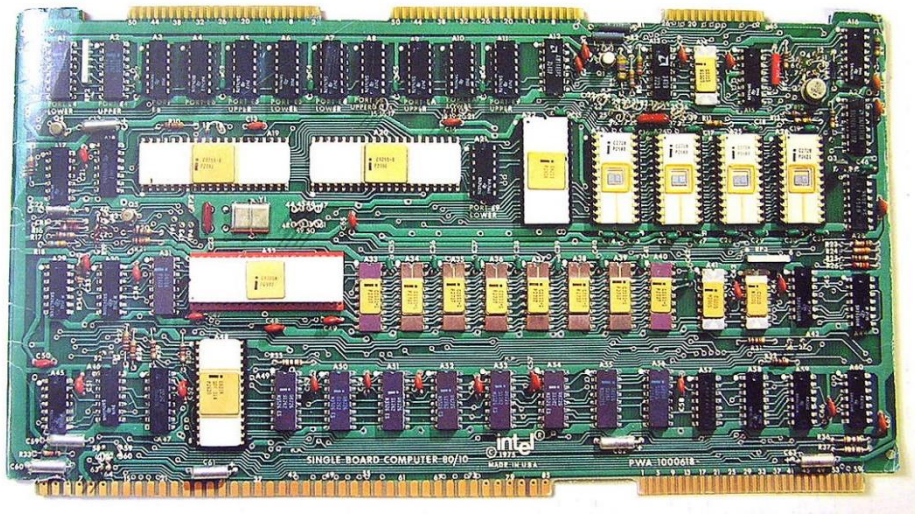

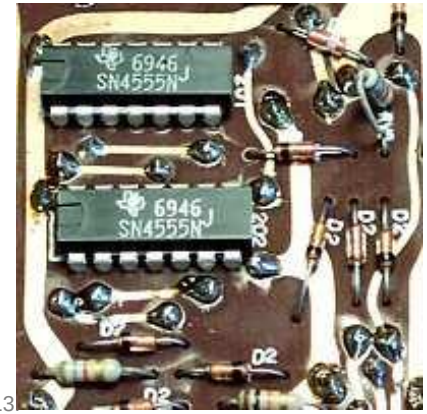

http://www.johnwolff.id.au/calculators/electronic/DTLChips.jpg

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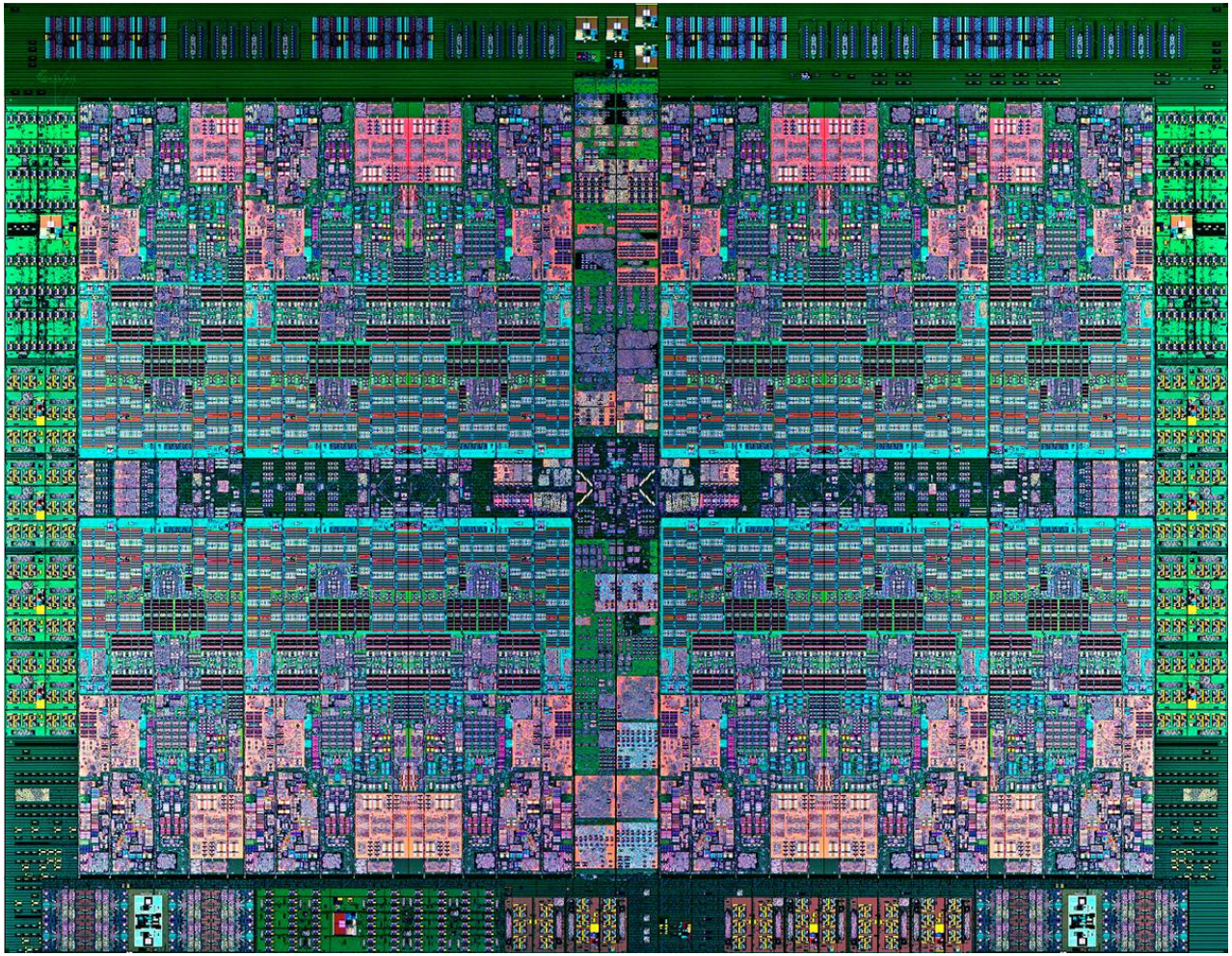
1980's

- Chips containing millions of transistors.



1980's

- Chips containing millions of transistors.
- Macintosh (Mac) computer debuted
  First computer to address how to use it; IBM followed
- Walkman China's global market conquest decimated US and European manufacturing in this decade
- 1985 British survey confirms an Ozone Hole over Antarctica
- 1987 the Montreal Protocol was signed banning CFC's, the major culprit in greenhouse gasses

http://upload.wikimedia.org

http://cache.wists.com/thumbnails

1990's

- Internet connected hundreds of millions of computers

http://i.huffpost.com-FASTEST-SLOWEST-INTERNET-SPEEDS-WORLD-CANADA

1990's Sustainability

UN Earth Summit/Eco '92, Rio de Janeiro

"Meeting the needs of today without compromising the needs of future generations"

- New Georgia Tech class: "Introduction to Sustainable Design"

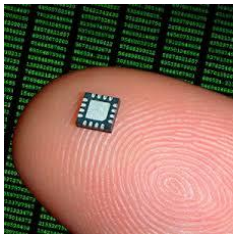
1. Made from renewable material; recycled in a closed loop
2. Non-toxic in use and disposal; must not disrupt ecosystem
3. Uses renewable energy (i.e., solar, wind, geothermal, wave, etc.)
4. Manufactured using a renewable energy source.
5. Transported using renewable energy.
6. Manufacture does not release toxins or disrupt ecosystem
7. Consumption can not outpace responsible (sustainable) production

2000

Ubiquitous computing- Chips designed into the environment

- Computers appear everywhere; invisible
- furniture, appliances, pictures, walls, cars, clothes all invisible and talking to one another.

http://www.siemens.com



http://www.personal.psu.edu

http://imgkid.com/cloud-computing-logo-png.shtml

Electronic Value good news & bad

- Electronics are central to our global economy; our way of life
- Reduced poverty; improved quality of life for many worldwide
- Transformed our communications, health care, transportation and agriculture industries.
- Brought about unprecedented connectedness globally
- But increasing demand has created excesses
- There is a growing surplus of end of life electronics (e-waste)

The Wasteful Electronics Paradigm

- Fabrication of microelectronics is a macro problem.
- We discard 3 million tons a year[1]; 2.5 million tons/year (EPA)
- We own 24 consumer electronic products on average[2]
- 75% of all computers ever sold are now surplus (U.S. National Safety Council)
- In 2010 we trashed 142,000 computers & 416,000 mobile devices every day[3]; 11-14% is recycled properly[4] (E-Stewardship)
- Only 2% of used PCs are ever reused by someone else[5]
- We consume twice as many goods as we did 50 years ago when happiness was at its peak[6]

1. *PC Magazine*, December 28, 2012.
2. Consumer Electronics Association, "Market Research Report: Trends in CE Reuse, Recycle and Removal, April 2008.
3.http://www.dosomething.org/actnow/tipsandtools/11-facts-about-e-waste; also, Facts and Figures on E-Waste and Recycling; Electronics TakeBack Coalition.
4. http://www.dosomething.olrg/tipand tools/11 -facts -about e-waste, retrieved 2013-001-16.
5. http://www.dosomething.org/actnow/tipsandtools/11-facts-about-e-waste, "Facts and Figures on E-Waste and Recycling," Electronics TakeBack Coalition. retrieved January 20, 2013
6. Taylor and Tilford, 2000, McKibben 2007.

Magnitude of the e-waste problem

- 50 million tons per year[1]
- 200-500% increase in developing nations.[2]
- 4,000 tons per hour of electronic waste is lost.[3]
- CO2 from IT equipment = that of the airline industry.[4]
- Volume increasing by 40% per year; 80% going to landfills[5]

1. Press Release, "Basel Conference Address Electronic Wastes Challenge. "November 27,2006., United Nations Environment Programme (UNEP). Available at: http://www.unep.org/Documents.Multilingual/Default.asp?DocumentID=485&ArticleID=5431&l=en
2. UN News Center news release: February 22, 2010 accessed at http://www.un.org/apps/news/story.asp?NewsID=33845&Cr=waste&Cr1#.UP2uHGfsZ8E
3. IBID. 5.
3. "Network Design on Reverse Logistics of Electronic Wastes Recycling. Xiangru Meng, Proceedings of the IEEE International Conference on Automation and Logistics, Quingdao, China. September 2008, p. 2110, http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=4636512&tag=1 accessed January 21, 2013.
4. IBID. 5.
5. http://www.greenfudge.org/wp-content/uploads/2010/09/e-waste-map-greenpeace.gif International Environmental Technology Center of the United Nations Environment Program (UNEP), (accessed May 19, 2015)

US E-Waste Waste Problem

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- Only 2% of used PCs are ever reused by someone else[5]
- No coherent national collection policy; Europe has WEEE[6]

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3.http://www.dosomething.org/actnow/tipsandtools/11-facts-about-e-waste; also, Facts and Figures on E-Waste and Recycling; Electronics TakeBack Coalition.
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5. http://www.dosomething.org/actnow/tipsandtools/11-facts-about-e-waste "Facts and Figures on E-Waste and Recycling," Electronics TakeBack Coalition. retrieved January 20, 2015.
6. http://ifixit.org/blog/4662/snapshot-of-worldwide-electronics-recycling-2013/

Why so much e-waste?

- Our techno-ego (wanting the latest and greatest)
- Computer life-cycle is 2-4 years; cell phones < 2 years
- 1/3 laptops can fail within 3 years[1]
- New technology conversion
- Software upgrades
- Moore's Law: processing power doubles every 24 months
- Result is cheap/disposable products[2]
- Planned obsolescence; cannot be repaired[3]

1. http://www.squaretrade.com/pages/laptop-rliability-1109, retrieved 2013-01-16.
2. www.elecronicstakeback.com, retrieved 2013-01-16.
3. "Ultra-inconvenient" p.1-6.August 15, 2012; wwwelecronicstakeback.com, retrieved 2013-01-16.

E-waste is lost value

- Computer life cycle energy (81% manufacture; 19% use)[1]
- Producing a 50 lb. computer & monitor requires:
  - 530 lbs. fossil fuel
  - 48 lbs. chemicals
  - 1.5 tons of water[2]
- 20,000 lbs. raw materials are used to make a 5 lb. computer.[3]

1. Energy Intensity of Computer Manufacturing: Hybrid Assessment Combining Process and Economic Input-Output Methods, Eric Williams, United Nations University, Environmental Science and Technology, Vol. 38, No. 22, Environmental Science and Technology p. 6166-6174, retrieved 2013-01-16.

2. Treehugger.com/clean-technology/crazy-e-waste-statistics.

3. *Natural Capitalism*: Creating the Next Industrial Revolution [Paul Hawken, Amory Lovins, L. Hunter Lovins].

Recycling Challenges

- Electronic products currently designed for the dump; poor design, difficult to take apart and repair
- Collection, sorting, packaging and transporting is costly
- Reclaiming precious metals is inefficient
- Shredding is low efficiency
- Glass is a particular problem; most is landfilled

Benefits of recycling electronics

- Prevent imbedded toxins and carcinogens (up to 1000 chemicals used to manufacture) from entering the waste steam. [1]
- Reduce the environmental costs of mining raw materials
- Save valuable materials & embedded energy
- Computer reuse vs. disposal generates more jobs[2]
- **Reduces the amount of carbon emitted during manufacture**

1. "Upcycle", William McDonough and Michael Braungart
2. Institute for Local Self reliance, "Recycling Means Business," 1997.

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Excess Carbon

- Electronics manufacturing emits significant amounts (carbon dioxide gas)
- CO2 Levels correlate directly to heat in the atmosphere; greenhouse effect
- Recycling ½ the e-waste in one household reduces carbon emitted into the atmosphere by 2,400 lbs. [1]
- Carbon footprint of electronics rivals that of the airline industry
- telecommunication, media and entertainment sectors are responsible for about 3% of all greenhouse gas emissions, as compared to 4-5% for the airline industry (when including all of its supporting infrastructure). [2]

1. http://oceanservice.noaa.gov/education/pd/oceans_weather_climate/media/carbon_dioxide.swfInstitute for Local Self reliance, "Recycling Means Business," 1997. (accessed May 20 2015)
2. Study: Carbon footprint of electronic Devices Can Rival Those of the Airline Industry, Siegel, R.P., http://www.triplepundit.com/2010/11/study-small-device-footprints-can-rival-those of-giant-machines/(accessed May 19, 2015)

Sustainability as Innovation Driver

Embrace Sustainable Innovation

- View Compliance as Opportunity
- Make Value Chains Sustainable Supply chains, Operations, Workplaces, Returns,
- Create sustainable products and services
- Developing New Business Model
- Create Next-Practice Platforms[1]

1. Nidumolu, R., Prahalad, C. K., and Rangaswami, M.R. (September, 2009), Why Sustainability is Now the Key Driver of Innovation, *Harvard Business Review*, (https://hbr.org/2009/09/why-sustainability-is-now-the-key-driver-of-innovation (accessed May 20, 2015).

Pursue eco-design strategies

Computer companies

Xerox • IBM• HP • Nokia • Motorola • AT &T • HP

Consumer goods companies

Bosch • Whirlpool • Philips • Toshiba • Hitachi • Sony • Electrolux• Kodak

Furniture companies

Herman Miller • Steelcase • Knoll • Haworth • IKEA

Automotive companies

BMW • Daimler-Chrysler • Fiat • Ford • GM • Volvo • Toyota

Future Challenges

What can we do going forward?

Overcome barriers to Sustainable Innovation such as:

- Concern that going green will cost more
- Green will create a competitive disadvantage
- Return on investment not evident
- Sustainability as a social responsibility as opposed to a business objective

Sustainable Strategies

1950's music .com

1. Focus on design (focus traditionally is on pollution prevention).

- About 80% of all product-related environmental impacts are determined during the product design phase.
- Goal: "design the environmental impacts out of the product and manufacturing processes"; translate thinking into reality.

2. Sustainable design education and research

- Industry-education partnerships (PIRL; DEE Lab)

3. Employ sustainable methods.

- LCA is now mainstream; refine to include environmental costs

1. Nidumolu, R., Prahalad An Introduction to EcoDesign Strategies – Why, what and how? Karsten S., Marcel Ha, gelüken, G. F., IZM, Berlin, Germany EcoDesignARC network (http://*www.**ecodesign**arc.info/.../EN_An%20Introduction%20to%20**EcoDesign**)*

4. Get help

Partnerships

Sustainable Electronics Initiative

- The Illinois Sustainable Technology Center (ISTC)
- …"consortium dedicated to the development and implementation of a more sustainable system for designing, producing, remanufacturing, and recycling electronic devices"
- Website, electronic library, informative weekly seminars/webinars addressing wide ranging environmental and sustainability issues
- http://www.sustainelectronics.illinois.edu

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DEElab. Design for Energy & Environment

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Education Partnerships

Linking Business, Design and Technology

University of Illinois at Urbana-Champaign

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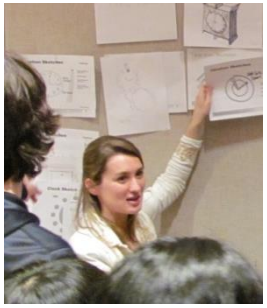
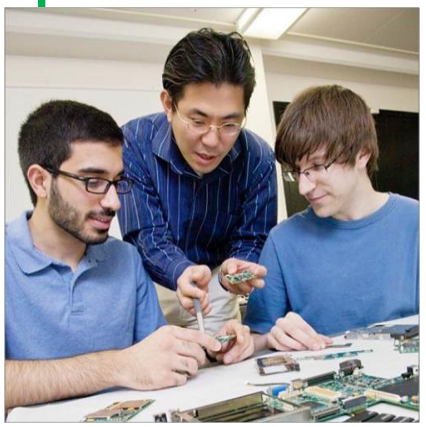
Innovation Teams



Creating New Uses for Recycled Laptops

Sustainable Electronics Initiative



Entrepreneurial Design exercise

- Sponsored by Dell, Inc.
- Discarded laptops without hard drives
- Goal: develop ideas to extend useful life prior to recycling
- Collaborative Course offered Spring 2012
- Faculty & students in industrial design, business, engineering and the sciences
- Guidance and feedback from experts at Dell, Inc.

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DEElab. Design for Energy & Environment

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Need

- 70% of the world's poorest people, 900 million, are small-scale farmers
- Access to water can increase food production and create income opportunities
- Drip irrigation is the most efficient way to grow crops in water scarce areas
- In developing countries:

  1 field flooded = 10 using drip irrigation

www.ideorg.org/ourtechnologies/dripirrigation.aspx , retrieved 2013-16-01.

Automated Drip Irrigation System

Sustainable Electronics Initiative

- A system for farmers in developing countries
- Laptop components
- Solar powered

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Recyclable Laptop

- Stanford's Bloom Computer, 2009
- Students from Stanford and Alto University (Finland)
- Disassemblv in 45 seconds

Photo courtesy of Autodesk http://www.govtech.com/technology/Stanford-Researchers-Make-Recyclable-Laptop.html

Future Challenges

- Better product lifecycle management (extraction, design, manufacture, use, recycling, recovery and disposal)[1]
- Greener design, reuse and recycling incentives[2]
- Expand Electronic Product Environmental Assessment tools (EPEAT)
- Reduce harm from U.S. exports
- Strengthen markets for recyclables by:
  - Ending subsidies for extraction of raw materials (metals, timber, oil and gas) that put recycling at a disadvantage.
  - Enacting Federal legislation (nationwide minimum-recycle-content laws)[3]
- Stop crushing and grinding products to recover metals
- Extend product life cycle; refurbish and reuse where possible[4]

1.http://www.epa.gov/wastes/conserve/materials/ecycling/taskforce/docs/strategy.pdf, accessed January 21, 2013.
2. "National Strategy for Electronics Stewardship," Interagency Task Force on Electronics Stewardship, July 20, 2011. http://www.epa.gov/wastes/conserve/materials/ecycling/taskforce/docs/strategy.pdf accessed January 21, 2013.
3. "Our Own Waste Enemy," Elizabeth Royte, http://www.mother.jones.com/environment/2009/05.
4. "Bringing technology to the poor," Lynda Carson, retrieved January 21, 2013 at http://www.thestreetspirit.org/July2005/compumentor.htm.

Helen Keller 1880-1968

“Is there anything worse than being blind? Yes, a man with sight and no vision.”
“Alone we can do so little; together we can do so much.”
“The marvelous richness of human experience would lose something of rewarding joy if there were no limitations to overcome. The hilltop hour would not be half so wonderful if their were no dark valleys to traverse. *(Quoted in Light in My Darkness, 1994)*

www.iperceptive.com

Gooogle images: accessed 08.13.12.

www.brailebug.org accessed 08.13.12.

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