Green Computing
TDDD50

www.ida.liu.se/~TDDD50

Real-time Systems Laboratory
Department of Computer and Information Science (IDA)
Linköping University
Sweden

January 23rd, 2014

Course Staff

- Examiner & Course leader
  Simin Nadjm-Tehrani
- Course assistant
  Ekhiotz Vergara (Seminar group placement)
- Seminar assistants (Absence after seminar 0)
  Simin Nadjm-Tehrani
  Maria Vasilevskaya
  Ekhiotz Vergara
- Course secretary
  LiseLott Lundberg (All matters to do with Ladok!)

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Course goals

- Identify and analyze the global impact of information & communication technologies (ICT)
  - ICT carbon footprint
  - product lifecycle
  - standards
- Identify mechanisms for reducing energy consumption of ICT
- Analyze sustainable ICT solutions/products
- Learn to read a research paper, present it in English, and lead a discussion in a group
- Summarize a research paper in a written report

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Education goals

- For Swedish students (hö
- Civing (och högskoleing.)
  - "insikt i aktuellt forskning
  - "utveckla och utforma pr hänsyn till … samhällets ekologiskt hållbar utveck
  - "förmåga att i såväl natio sammanhang muntligt o grupper klart redogöra fö
- So we are right on the spot

These goal celebrations are getting out of control

Structure of the course

- Lectures
  - 3 lectures
    - Introduction to the course, rules of the game, minimum terminology to start you off reading, and get ready for the Data Centre Visit!
- Seminars
  - 1 introductory seminar (*seminar 0*)
  - 7 regular seminars (14 research papers)

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Lecture1-3

- Two types of information
  - How can a student prepare to pass this course?

  - What is the basic terminology one is expected to know to actively take part in the seminars

http://openclipart.org/detail/28016/roadsign-keep-left-by-anonymous
http://openclipart.org/detail/75799/registry-book-by-wakro

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Examination

Based on:

- Written report on the assigned paper
- Presentation of the assigned paper
- Seminars work
  - **Active participation** in discussions
- Attendance to all seminars is **compulsory**
  - Talk to your teacher in advance in case of justified absence
  - Ensure you have a **copy of the paper** discussed in front of you, in the seminar

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'Our pupils go on many foreign trips – some of them arranged by the school'

http://www.telegraph.co.uk/news/matt/?cartoon=10578560&cc=10545545

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Grades

Incremental requirements:

- **Grade 3**
  - Attend all seminars and participate in all discussions
  - Satisfactory presentation and leading of discussion for the assigned paper
  - Write report about the assigned paper (see template)
- **Grade 4**
  - High quality form and content report
  - Prepared activity in the seminar discussion
- **Grade 5**
  - Extended report, including:
    - proposal of alternative ideas on the paper solution
    - extended related work with at least one more reference

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Important dates and procedures

23-28th January	Selection of article
30th January	Article assignment
31th January	Introductory seminar
26th March	Deadline to send in first version of your report

It is recommended to hand in the report **one week** after your presentation

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Muddy card evaluation

- Mid-course checkpoint
- White card filled by the students
  - Anonymous
  - Things they like, or would like to improve in the course
- Will be done
  - At the end of seminar 3
  - Results will be available on the website

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Web evaluation KURT (2013)

- One student: I am not sure what I learnt
  - One gets as much as one puts in the course
  - Use this unique set up for new learning capabilities!
- The student background was too heterogeneous
  - We try to put the more advanced students in one seminar group
  - Early indecision (drop outs) and merges mess up for us

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Thesis projects

- Consider this area as a possible area for your thesis project!

Anton Thomasson

M. Asplund, A. Thomasson, E. J. Vergara, and S. Nadjm-Tehrani, **Software-related Energy Footprint of a Wireless Broadband Module**, in *The 9th ACM International Symposium on Mobility Management and Wireless Access (MobiWac)*, ACM, November 2011.

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Questions?

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Terminology

- Introduction to sustainability
- Life-Cycle of ICT products
- Eco-labelling and standards

Many thanks to Jordi Cucurull
For earlier versions of this course material

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Terminology

- **Introduction to sustainability**
- Life-Cycle of ICT products
- Eco-labelling and standards

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Sustainability

- a multi-faceted concept frequently invoked in environmental discourse. Its precise meaning as well as differences to similar concepts such as sustainable development are a matter of on-going argument. Most interpretations focus on the property of environmental, social or socio-ecological systems to maintain important indicators of system integrity, functioning or well-being over extended periods of time.

Wikipedia

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Global Warming

- Human activities are affecting the natural environment
- An example is the massive production of CO_2

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Global Warming

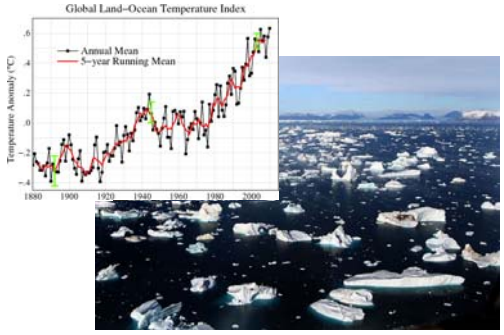

Photo by Mila Zinkova [CC-BY-SA-3.0 (www.creativecommons.org/licenses/by-sa/3.0)]

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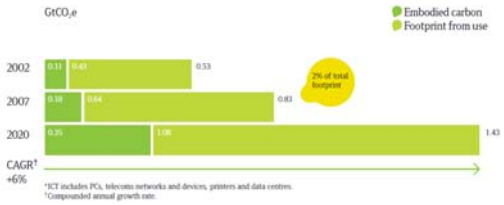
Global ICT footprint (CO_2)



http://www.smart2020.org/publications/

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Definition of Green Computing

Different definitions are possible:

- Reduction of the GHG emissions
- Reduction of energy wastes
- Reduction of energy bill
- Reduction of energy consumption

While maintaining (or considering the loss in) the quality of service

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Solutions for each definition

- Reduction of the environmental impact
  - Use renewable energy sources (GHG emissions)
  - Design of low power components
  - Responsible disposal and recycling
- Reduction of energy wastes
- Reduction of energy bill
- Reduction of energy consumption

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Solutions for each definition

- Reduction of the environmental impact
- Reduction of energy wastes
  - Locate power drain points close to power plants
  - Exploit environmental characteristics (e.g., cooling, sun)
- Reduction of energy bill
- Reduction of energy consumption

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Solutions for each definition

- Reduction of the environmental impact
- Reduction of energy wastes
- Reduction of energy bill
  - Exploit volatile electricity prices
  - Create and enforce regulatory support
- Reduction of energy consumption

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Solutions for each definition

- Reduction of the environmental impact
- Reduction of energy wastes
- Reduction of energy bill
- Reduction of energy consumption
  - Enforce energy proportionality
  - But … Consider performance guarantees

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Green ICT vs. ICT for Green

- Green ICT
  - Reduction of the ICT's environmental footprint
  - E.g., Energy-aware data centers
- ICT for Green
  - Use ICT technologies to reduce the environmental footprint of other processes and sectors
  - E.g., smart grid, smart building

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Benefits (cross-definition)

- Environmental
  - ICT respectful towards the environment
  - Less production of CO_2 and other contaminants
- Economical
  - Reduction of electricity bill
  - Less infrastructure for same service (power supplies, cooling systems...)
  - Government financial incentives
- Public relations
  - Marketing
  - Competitiveness

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Sustainability affects company's image

- Carbon Disclosure Project
  - Database with corporate climate change information
  - Companies disclose
    - Gas emissions
    - Strategies to prevent climate change

https://www.cdproject.net

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Sustainability affects companies image

- Cool IT (Green Peace)
  - Initiative to track corporate climate leadership
  - Most influential IT brands are analysed according to:
    - Efforts to provide solutions to reduce greenhouse emissions
    - Initiatives to reduce their own emissions
    - Political advocacy to support climate and energy policies

http://www.greenpeace.org/international/en/campaigns/climate-change/cool-it/

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Terminology

- Introduction to sustainability
- **Life-Cycle of ICT products**
- Eco-labelling and standards

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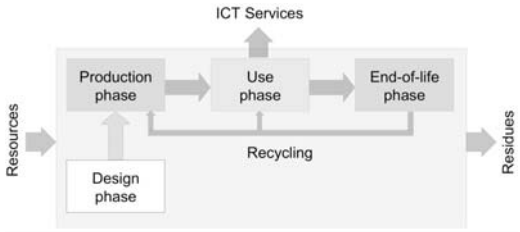
Holistic approach: Life-Cycle of ICT



Lorenz M. Hilty. Information Technology and Sustainability: Essays on the Relationship between Information Technology and Sustainable Development, Books on Demand, 2008 ISBN: 978-3837019704

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Life-Cycle Assessment (LCA)

- All phases of the chain must be considered
  - Consumption of material and energy
  - Use of some infrastructure
- Life-Cycle Assessment (LCA)
  - Environmental impact of a product in entire life-cycle
  - Materials, energy and infrastructure have their own life-cycles
  - Recursive study of them
- LCA analysis performed with
  - LCA tools: *SimaPro*, *Umberto*…
  - Life-cycle inventory database: *Ecoinvent*...

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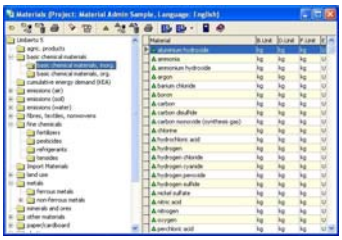
Umberto (i)

Management of materials



http://www.umberto.de

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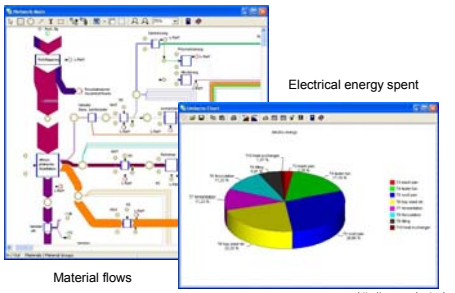
Umberto (ii)



Electrical energy spent

Material flows

http://www.umberto.de

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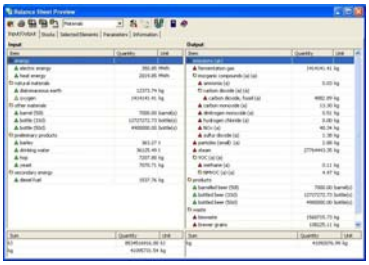
Umberto (iii)

Materials from flow network calculation



http://www.umberto.de

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ICT production vs. usage

Comparison of phases in Desktop PCs

Production in China consumes 2.4 GJ

One year usage consumes 0.8 GJ

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ICT production vs. usage

- Usage phase offsets production after 3 years
  - This increases to 6 years if other environmental aspects defined in the Eco-Indicator '99 methodology are aggregated
  - Dependent on electricity supply mix
- Length of usage phase is a very relevant parameter
  - Short software innovation cycles with increasing hardware requirements are ecologically disastrous
  - Usage phase should be extended
    - Trade-off extension vs. reduced consumption of new devices

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ICT End-of-life (i)

- Waste from electrical and electronic equipment (e-Waste)
- e-Waste has become a serious problem
  - Total annual global volume around 40 million tonnes
  - Treatment is a challenge, recycling is the key
    - Recycling metals can save up 20-25% of production costs

39 Image under CC license by nickwheeleroz on Flickr

ICT End-of-life (ii)

- Informal recycling
  - Informal industry in emerging economies
  - Health and environmental impacts not considered
  - No or poor safety measures while manipulation
  - High levels of contaminants in the activity areas
    - Air, bottom ash, dust, soil, waters…

Pictures by courtesy of Technology and Society Lab, Empa Materials Science and Technology, Switzerland

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Terminology

- Introduction to sustainability
- Life-Cycle of ICT products
- **Eco-labelling and standards**

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ENERGY STAR

- Set of **energy** performance specifications that qualified products must fulfill

"If every home office product purchased in the United States this year met ENERGY STAR requirements, we would:

- *Save more than $100 million in annual energy costs*
- *Prevent 1.4 billion pounds of greenhouse gases, equivalent to emissions from 125,000 cars*
- *Save more than 900 million kWh of electricity."*

http://www.energystar.gov

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ENERGY STAR Requirements for Computers (5.2)

- Defines categories of computers
  - Desktop computers, integrated desktop computers, notebooks, workstations, game consoles, small-scale servers, thin clients
- Defines operational modes
  - Off mode, sleep mode, idle mode, active mode
- Defines maximum annual consumption for each category
  - Tables with non-active operational mode weighting (% time idle, sleep...)
  - Tables with maximum annual energy according to operational mode weighting defined (Typical Energy Consumption - TEC)
- Defines test procedures to qualify products

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ENERGY STAR – an example

- Example with desktop computer category B (2 cores, >= 2 GB)

Time spent in mode	Weighted time in mode
T_{off}	55%
T_{sleep}	5%
T_{idle}	40%

$$E_{TEC}=(8760/1000)\cdot(P_{off}\cdot T_{off}+P_{sleep}\cdot T_{sleep}+P_{idle}\cdot T_{idle})$$

E_{TEC} for category B computer ≤ 175.0 (kWh)

P_{off}, P_{sleep}, and P_{idle} must be measured and fed into the formula that must give less than or equal to 175 kWh to qualify the product

http://www.energystar.gov

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ENERGY STAR Other products

- ENERGY STAR Program Requirements for Displays
  - Defines criteria for qualifying products
    - Power source, television tuners, automatic brightness control, external power supply, power management requirements
  - Defines operational mode requirements
    - Maximum consumption in off and sleep modes
    - Maximum consumption in on mode
      - Depends on size, resolution and brightness settings
  - Defines test procedures to qualify products
- ENERGY STAR provides a database for qualified products
  - http://www.eu-energystar.org/en/database.shtml

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RoHS - EU Directive 2002/95/EC

- Restriction of use of certain Hazardous Substances (RoHS)
  - In electrical and electronic equipment
  - To protect human health and environment
  - For products put on the market since 1st July 2006
- Restricted substances
  - Lead
  - Mercury
  - Cadmium
  - Hexavalent chromium
  - Polybrominated biphenyls (PBB)
  - Polybrominated diphenyl ethers (PBDE)

http://www.rohs.gov.uk/
http://ec.europa.eu/enterprise/policies/european-standards/harmonised-standards/restriction-of-hazardous-substances/index_en.htm

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EPEAT / IEEE P1680

- Global registry of electronic products
  - Covers design, production, use, and disposal of products
  - Operation and criteria based on IEEE 1680 standards
  - 23 required criteria and 28 optional
- Products registered and declared by manufacturers
  - Independent verification of their claims
  - Fast product presence in the register
- Environmental product ranking
  - Bronze: Meets all 23 required criteria
  - Silver: Bronze plus 50% of the optional criteria
  - Gold: Bronze plus 75% of the optional criteria

http://www.epeat.net

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EPEAT Criteria

- Criteria categories
  - Reduction/elimination of environmentally sensitive materials
  - Materials selection
  - Design for end of life
  - Product longevity / life cycle extension
  - Energy conservation
  - End of life management
  - Corporate performance
  - Packaging
- EPEAT enforces products to meet ENERGY STAR requirements and RoHS EU directive

http://www.zerowaste.org/epeat_devel/files/EPEAT%20Summary%20060113.pdf

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