

Classifying Green Software Engineering – The GREENSOFT Model

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Outline

- I. What is Green and Sustainable Software Engineering?
- II. A Generic Model for Sustainable Software Engineering
- III. Influences of Software on Energy Consumption
- IV. Summary & Challenges





Motivation 1: Energy Consumption of ICT is still increasing



Datenquelle: Fraunhofer IZM; Fraunhofer ISI (2009): Abschätzung des Energiebedarfs der weiteren Entwicklung der Informationsgesellschaft, S. 115





Motivation 2: An Energy Label for Software is missing!



ENERGY STAR® is a registered mark owned by the US government





Motivation 3: Windows® Hardware Requirements

Windows version	Processor	Memory	Hard disk
Windows 95 ^[4]	25 MHz	4 MB	~50 MB
Windows 98 ^[5]	66 MHz	16 MB	~200 MB
Windows 2000 ^[6]	133 MHz	32 MB	650 MB
Windows XP ^[7] (2001)	233 MHz	64 MB	1.5 GB
Windows Vista ^[8] (2007)	800 MHz	512 MB	15 GB
Windows 7 ^[9] (2009)	1 GHz	1 GB	16 GB
Windows 8 ^[10] (2012)	1 GHz	1 GB	16 GB

Source: http://en.wikipedia.org/wiki/Software_bloat



What is Green and Sustainable Software?

- "Green and Sustainable Software is software
- whose direct and indirect negative impacts on economy, society, human beings, and environment
- that result from development, deployment, usage, and disposal of the software are minimal and/or
- which has a positive effect on sustainable development"

What is Sustainable Software Engineering?

"Sustainable Software Engineering is the art of

- defining and developing software products in a way so that
- negative and positive impacts on sustainability that
 - result or are expected to result from the software product
- over its whole lifecycle
 - are continuously assessed, documented and optimized"



II. A Generic Model for Green and Sustainable Software Engineering



GREENSOFT Model Green and Sustainable Software Model Life Cycle of Software Products Development Usage End of Life First-order Effects Second-order Effects Third-order Effects **Sustainability Criteria and Metrics** Directly Related Indirectly Related Common Quality Criteria Criteria and Criteria and and Metrics Metrics Metrics **Procedure Models** Develop Administrate Use Purchase **Recommendations and Tools** For Developers For For Administrators Users For Purchasers

The GREENSOFT Model



	Development	Usage	End of Life
Third-order Effects	 - Changes in software development methods - Changes in corporate organizations - Changes in life style 	 - Rebound effects - Changes of business processes 	 - Demand for new software products
Second-order Effects	 - Globally distributed development - Telework - Higher motivation of team members	 - Smart grids - Smart metering - Smart buildings - Smart logistics - Dematerialization 	 - Media disruptions
First-order Effects	 - Daily way to work - Working - conditions - Manuals - Business trips - Transportation - Energy for ICT - Packaging - Office HVAC - Data medium - Office lighting - Download size 	 - Accessibility - Hardware requirements - Software induced resource consumption - Software induced energy consumption 	 - Backup size - Long term storage of data (due to legal issues) - Manuals - Data conversion - Data medium (for future use) - Packaging
	Development Distribution	Usage	Deactivation Disposal
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Overview of a GSE-Process Model





Overview of a GSE-Process Model







Overview of a GSE-Process Model







III. Influences of Software on Energy Consumption

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>>	Measurement	Overview Ver Measurement Details Ver System Under Test Details	1						
	System L	Inder Test Details					Green Softwa	nS	of
	Application Compiler / Interpreter	Firefox 3.6.22		Power Readings	Performance Readings	Task Log			
	Runtime Environment	32 Bit Subsystem	Te	est Series Label		Begin	End		^
4	Operating System	Windows 7, 64 Bit, Build 7601		01	16.09.20	11 12:00:03	16.09.2011 12:08:55		
gationsbereid	Hardware - Intel Core i3 CPU 540 @3.07GHz (4 Cores) - Asrock H55M-LE Rev. 1.03 - 4 GB RAM, 3.68GB usable - Intel H55 Express Chipset		02 03 04	16.09.20 16.09.20 16.09.20	011 12:10:11 011 12:20:11 011 12:30:11	16.09.2011 12:19:02 16.09.2011 12:29:03 16.09.2011 12:39:02			
Navig		- Intel HD Graphics - Realtec RTL 8111DL Gigabit Ethernet NIC PCI-E - HDD Seagate 465 GB	-	05	16.09.20	011 12:50:11 011 13:00:11	16.09.2011 12:59:03 16.09.2011 13:09:02	•	
		- Cooler Master 600W Silent Pro Gold power supply		07	16.09.20	011 13:40:11	16.09.2011 13:49:01		•
	Close De	lete		Delete All Power Readings	Delete A Performance Re	II eadings	Delete All Task Log Items		





Significance Report



Joomla 1.5.23 No Cache vs. Cache

Compares different configurations of the Web CMS Joomla. One configuration does not use the hard disk cache to store HTML fragments of web sites for retransmission in subsequent requests, whereas the other uses such a hard disk cache.

Systems Under Test

1.	Application:	joomla 1.5.23 (without hard disk	Hardware:	CPU: 2 Intel Xeon Du
		cache for HTML fragments)		RAM: 2GB
	Compiler/Interpreter:	PHP 5.3.2-1Ubuntu4.9		Board: Supermicro P BIOS: Rev 1.2b
	Runtime Environment:	Apache 2.2.14		CD-ROM: ATAPI CD-
				ROM ATAPI Model D

Operating System: Ubuntu SMP 10.04 LTS (Linux 2.6.32-32-generic-pae)

Test Series	Duration	Energy
01	00:10:00	33,833 Wh
02	00:10:00	34,204 Wh
03	00:10:00	33,966 Wh

30	00:10:00	33,9	910 Wh
Avera	age: 00:10:00	33,9	937 Wh
Standard Deviat	ion: 00:00:00	0,3	163 Wh
Type of Perf.	Average Perf.	Std.Dev. Perf.	Max Perf.
CPU% Idle	49,298	25,455	100,000
CPU% Total	50,702	25,455	100.000

 Application: joomla 1.5.23 (with hard disk cache for HTML fragments)
 Compiler/Interpreter: PHP 5.3.2-1Ubuntu4.9

completion for some sources

Runtime Environment: Apache 2.2.14

Operating System: Ubuntu SMP 10.04 LTS (Linux 2.6.32-32-generic-pae)

PU: 2 Intel Xeon Dualcore CPU 2.40 GHz AM: 2GB oard: Supermicro P4BP8-G2/P4DPE-G2 IOS: Rev 1.2b D-ROM: ATAPI CD-ROM: Pioneer DVD-OM ATAPI Model DVD 1068-1022

Hardware: CPU: 4 h

RAM: 20 Board: 5

BIOS: Re

CD-RON

ROM ATAPI Model DVD 1068-1022

Simultaneous Users: 1 Measurement Phases:



Significance Test (T-Test)

Null Hypothesis: The mean energy consumption induced by SUT 1 and SUT 2 is equal

Alternative Hypothesis: The mean energy consumption induced by SUT 1 and SUT 2 is not equal

Alpha: 0,010

P-Value: 0,000000000000000

Interpretation: The mean energy consumption induced by SUT 1 and SUT 2 is not equal



Measuring Joomla: Setup of the Testing Website

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- Content:
 - text passages from EU legal documents
 - self-taken photographs
 - graphics from R&D project
- Navigation area:
 - 10 articles without optimized images
 - 10 articles with optimized images
 - list of 100 generic articles to simulate paging



Measurement results

- Comparing different scenarios:
 - common techniques reducing resource consumption of websites do also reduce the energy consumption
 - approx. savings: 4.23 % (see table below)
 - may be further increased by implementing additional suggestions

	Scenario	Load level	Energy (AVG)
a)	Joomla without any improvements (reference system)	50%	39.250 Wh
b)	Joomla with application level cache, optimized images and compression	50%	37.573 Wh

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IV. Summary & Challenges



Visualizing of Energy & Web: Green Power Indicator

- A tool to visualize the power quality of a website
- For users in the life cycle phase usage/maintanance
- Visualization to create awareness







Challenges

- What is energy-efficient Software?
 We need reproducible metrics and measurement, and we need energy-aware software architectures!
- How can we produce energy-efficient Software?
 We need process models which contain "green" ideas!
- How can we reinforce energy-efficient Software? customer requirements, norms, certificates, teaching ...



Thank you for your attention!

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