Green Software Engineering

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Outline

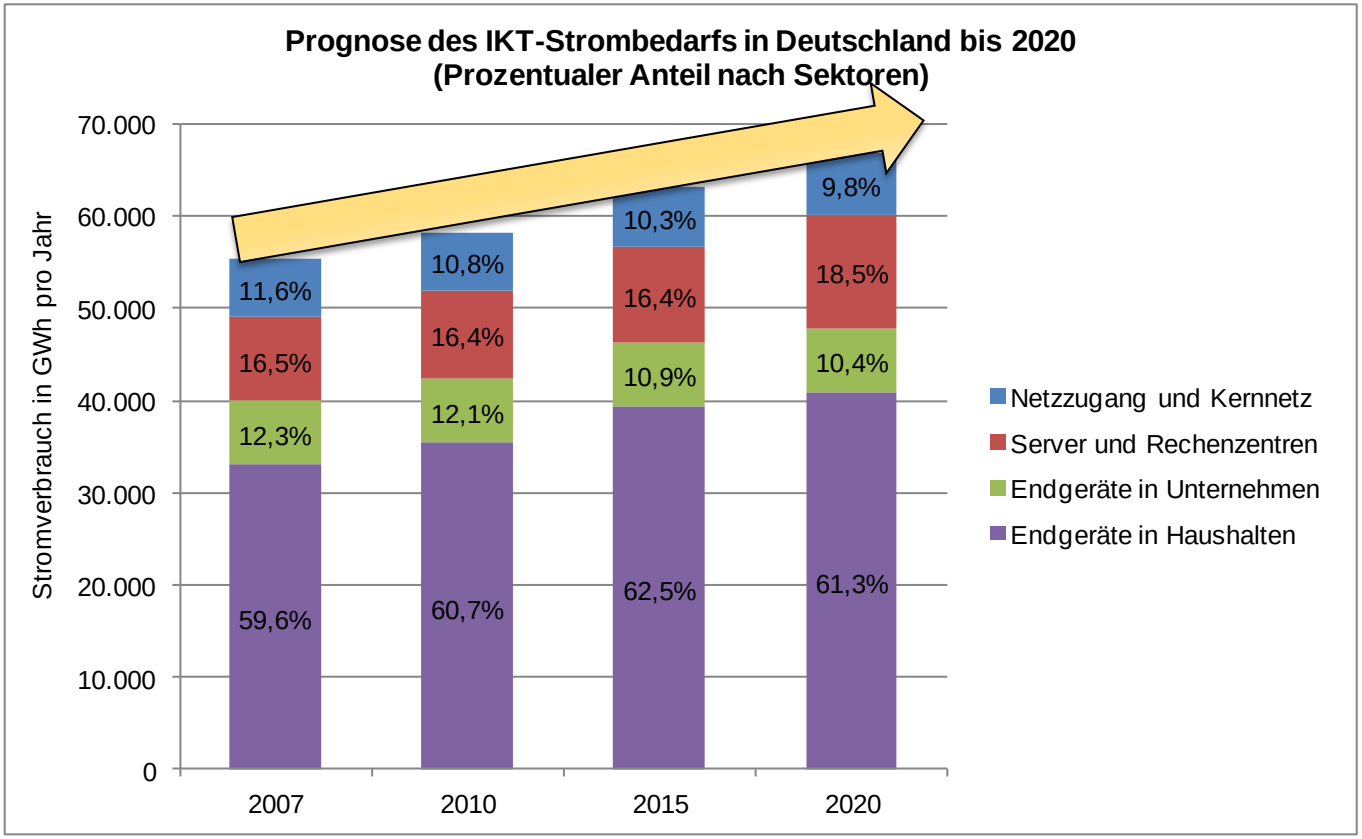
I. What is Green and Sustainable Software Engineering?

II. A Generic Model for Sustainable Software Engineering

III. Influences of Software on Energy Consumption

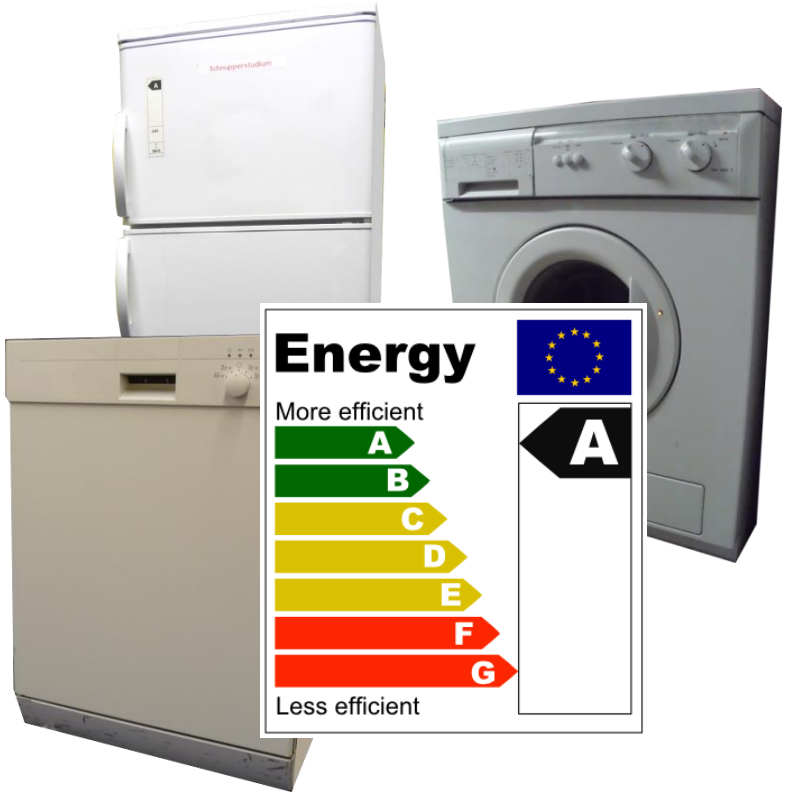
IV. Summary & Challenges

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"

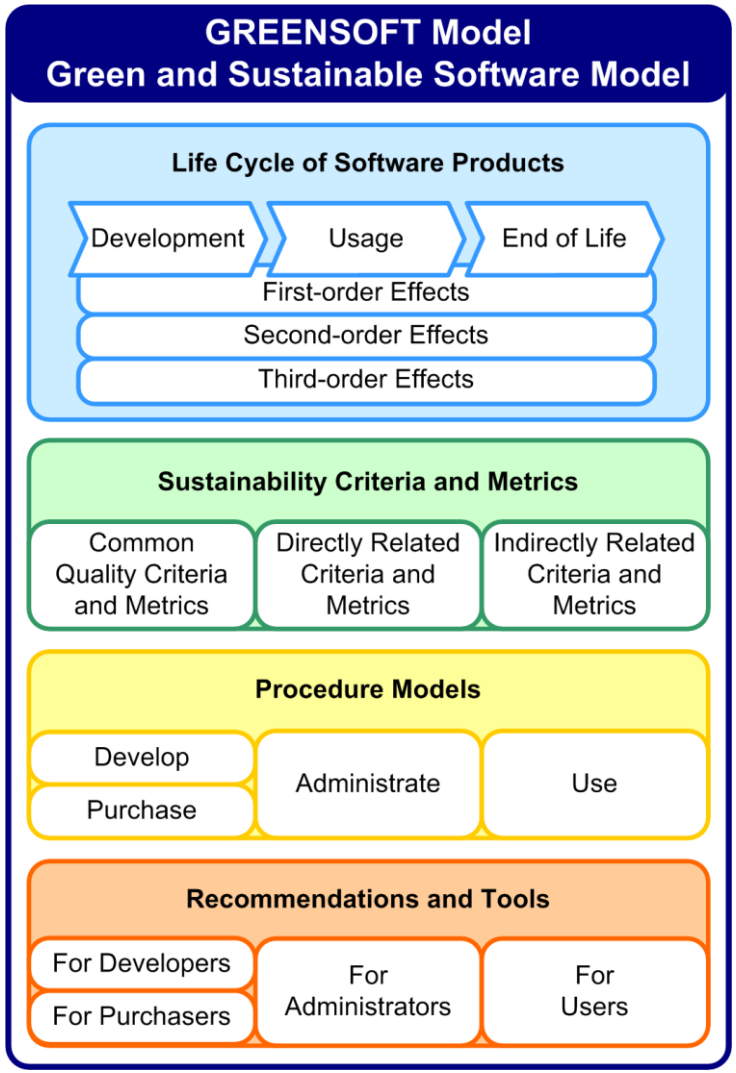
What is Sustainable Software Engineering?

"***Sustainable Software Engineering*** is the art of

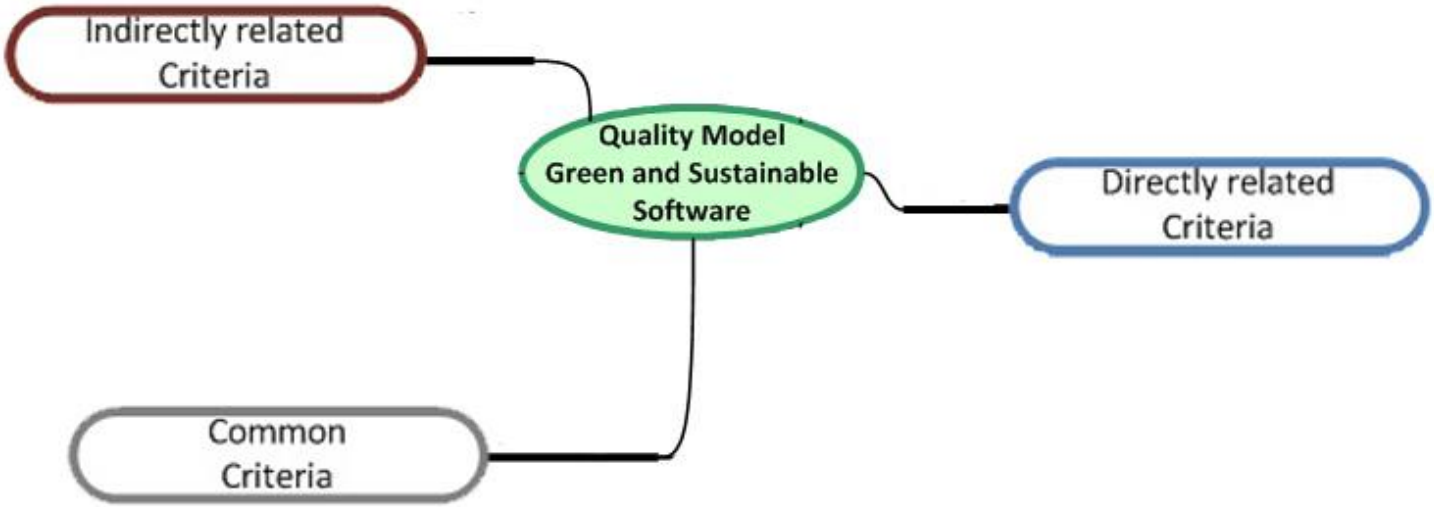
- defining and developing software products in a way so that
- negative and positive impacts on sustainability that result or are expected to result from the software product
- over its whole lifecycle
- are continuously assessed, documented and optimized"

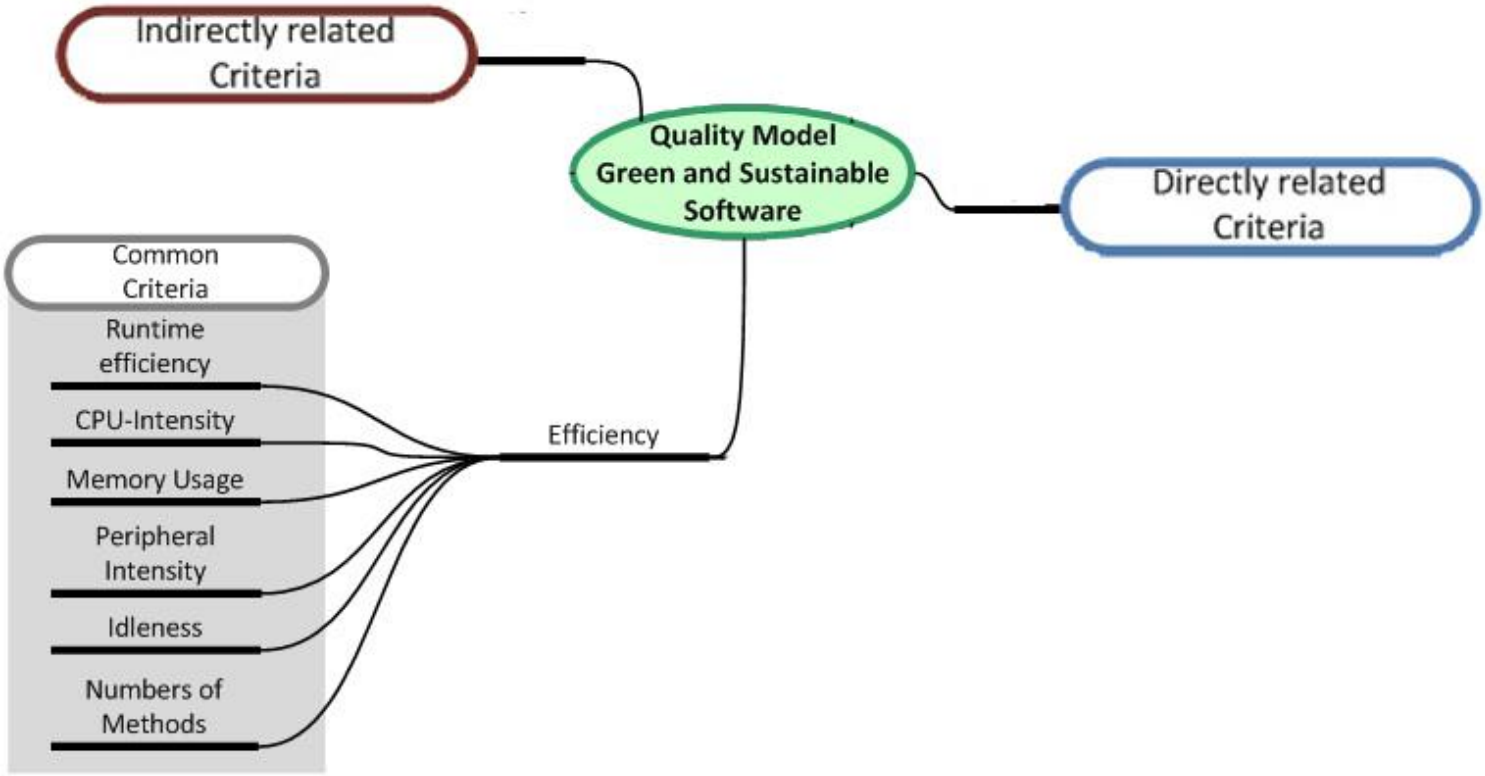
II. A Generic Model for Green and Sustainable Software Engineering

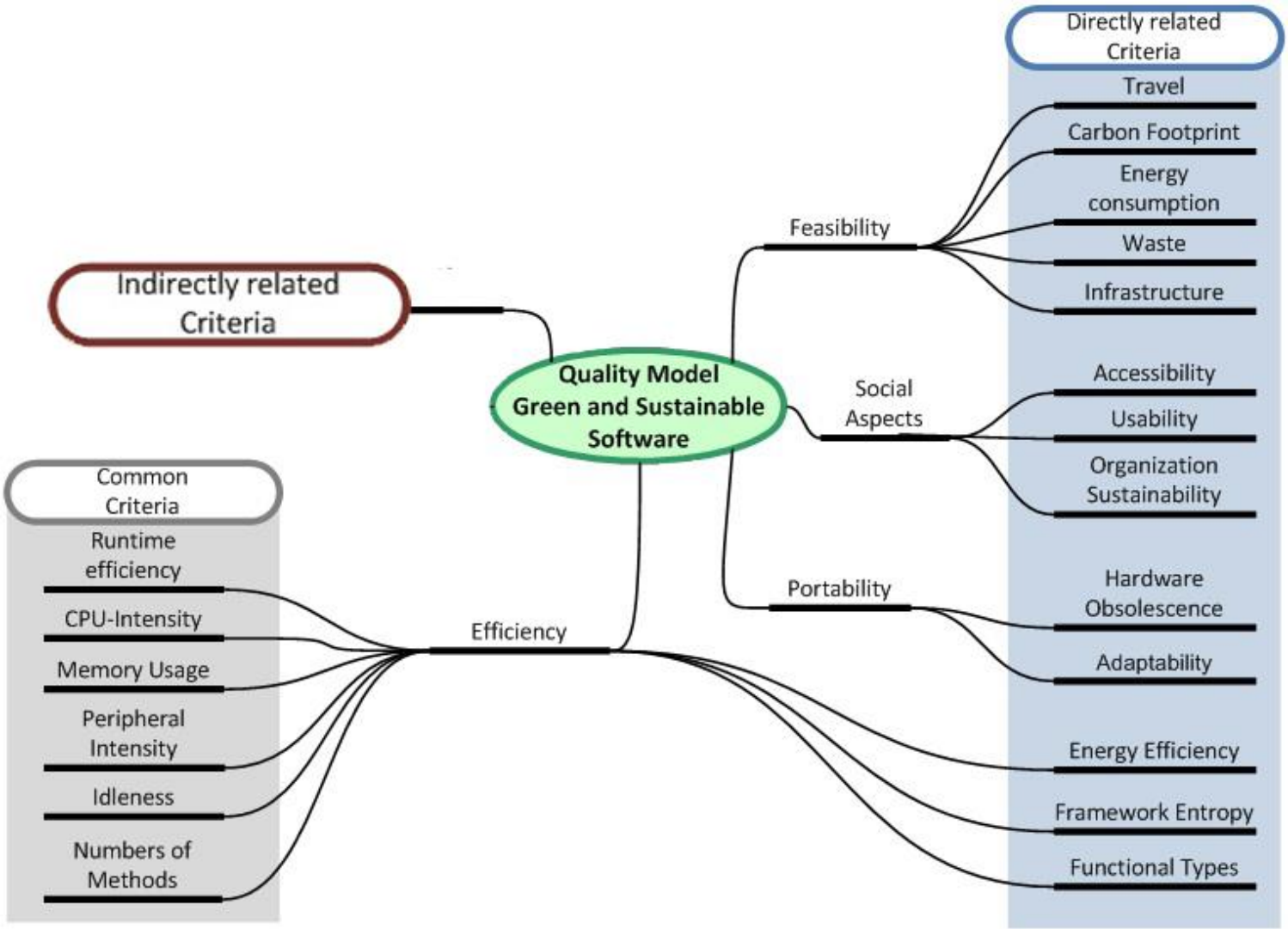
The GREENSOFT Model

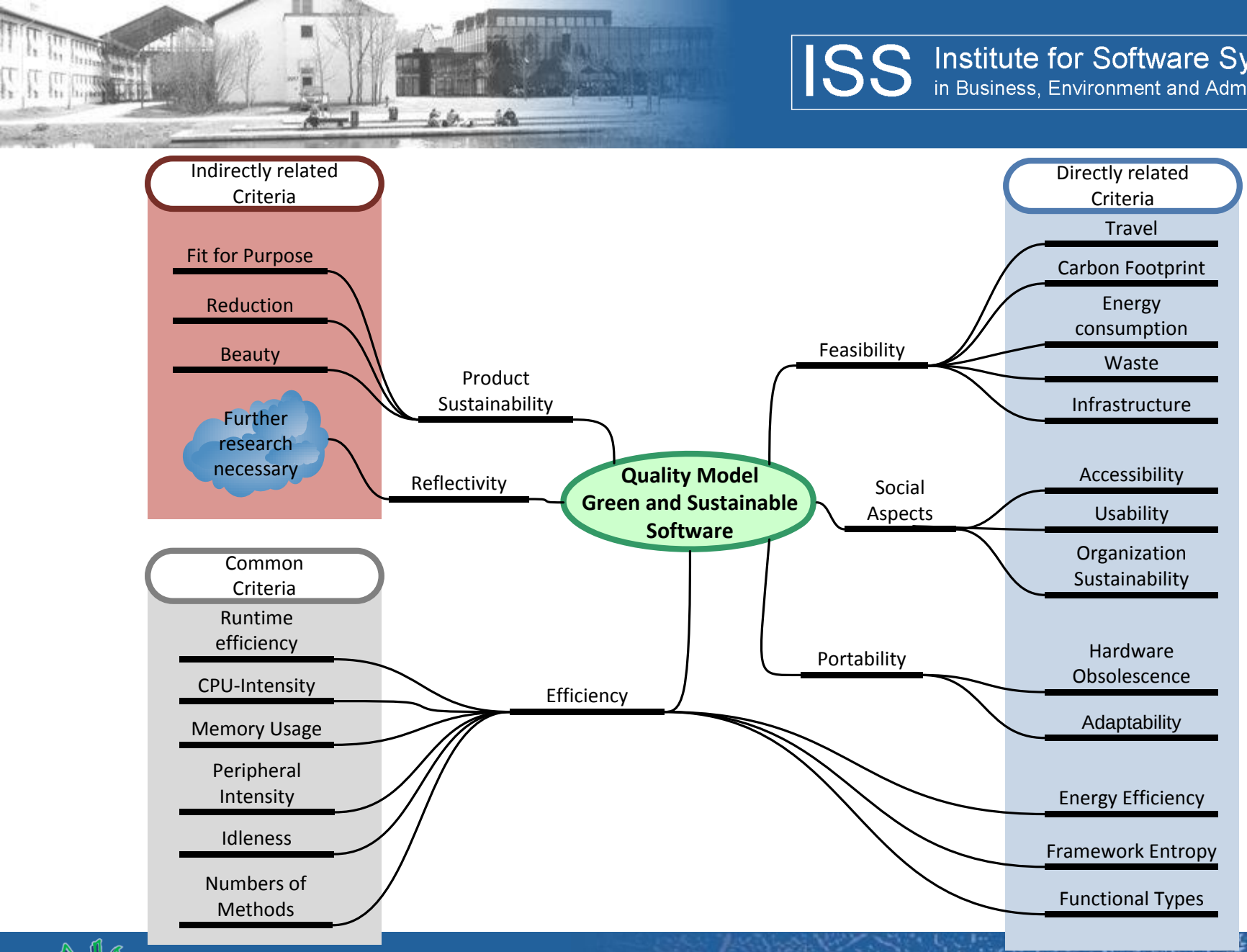


	Development	Usage	End of Life
Third-order Effects	- ... - Changes in software development methods - Changes in corporate organizations - Changes in life style	- ... - Rebound effects - Changes of business processes	- ... - Demand for new software products
Second-order Effects	- ... - Globally distributed 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 - Business trips - Energy for ICT - Office HVAC - Office lighting - … - Manuals - Transportation - Packaging - Data medium - Download size	- … - Accessibility - Hardware requirements - Software induced resource consumption - Software induced energy consumption	- … - Backup size - Long term storage of data (due to legal issues) - Data conversion (for future use) - ... - Manuals - Data medium - Packaging
	Development → Distribution	Usage	Deactivation → Disposal


Indirectly related Criteria
Quality Model Green and Sustainable Software
Directly related Criteria
Common Criteria


Indirectly related Criteria
Quality Model Green and Sustainable Software
Directly related Criteria
Common Criteria
Runtime efficiency
CPU-Intensity
Memory Usage
Peripheral Intensity
Idleness
Numbers of Methods
Efficiency


Directly related Criteria
Travel
Carbon Footprint
Energy consumption
Waste
Infrastructure
Feasibility
Indirectly related Criteria
Quality Model Green and Sustainable Software
Social Aspects
Accessibility
Usability
Organization Sustainability
Common Criteria
Runtime efficiency
CPU-Intensity
Memory Usage
Peripheral Intensity
Idleness
Numbers of Methods
Efficiency
Portability
Hardware Obsolescence
Adaptability
Energy Efficiency
Framework Entropy
Functional Types


Indirectly related Criteria
Fit for Purpose
Reduction
Beauty
Further research necessary
Product Sustainability
Reflectivity
Common Criteria
Runtime efficiency
CPU-Intensity
Memory Usage
Peripheral Intensity
Idleness
Numbers of Methods
Efficiency
Quality Model Green and Sustainable Software
Feasibility
Social Aspects
Portability
Directly related Criteria
Travel
Carbon Footprint
Energy consumption
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Accessibility
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Adaptability
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Framework Entropy
Functional Types

Life Cycle Thinking for Software Products

Life Cycle Thinking for Software Products

Life Cycle Thinking for Software Products

Sustainability relevant criteria

Life Cycle Thinking for Software Products

Sustainability relevant criteria

Starting points for activities

Sustainability Relevant Criteria

- …
- Transportation for daily way to work
- Working conditions (offshore workers)
- Business trips
- Energy for ICT
- Office lighting
- Office HVAC

Sustainability Relevant Criteria

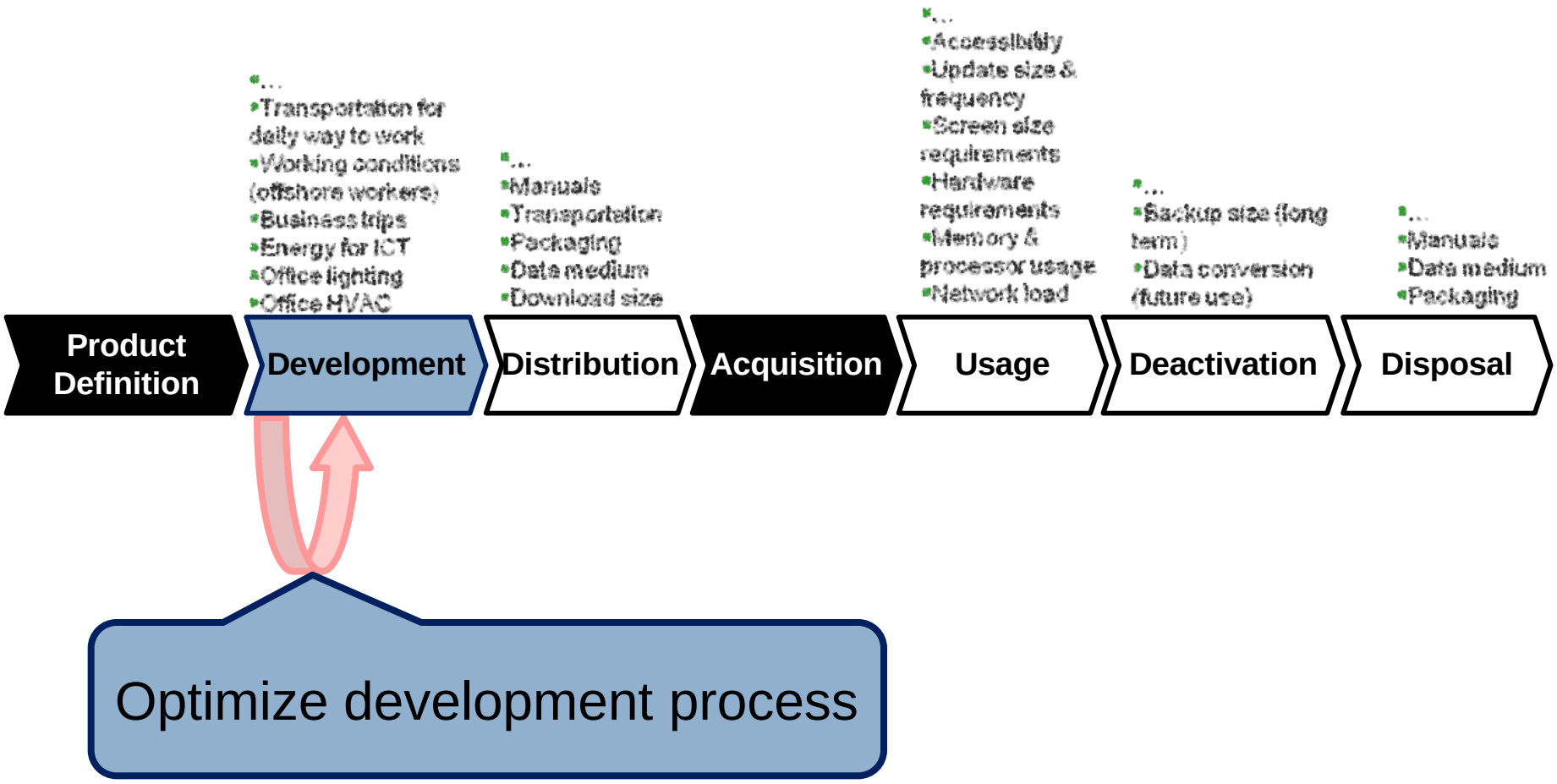
- …
- Manuals
- Transportation
- Packaging
- Data medium
- Download size

- …
- Manuals
- Data medium
- Packaging

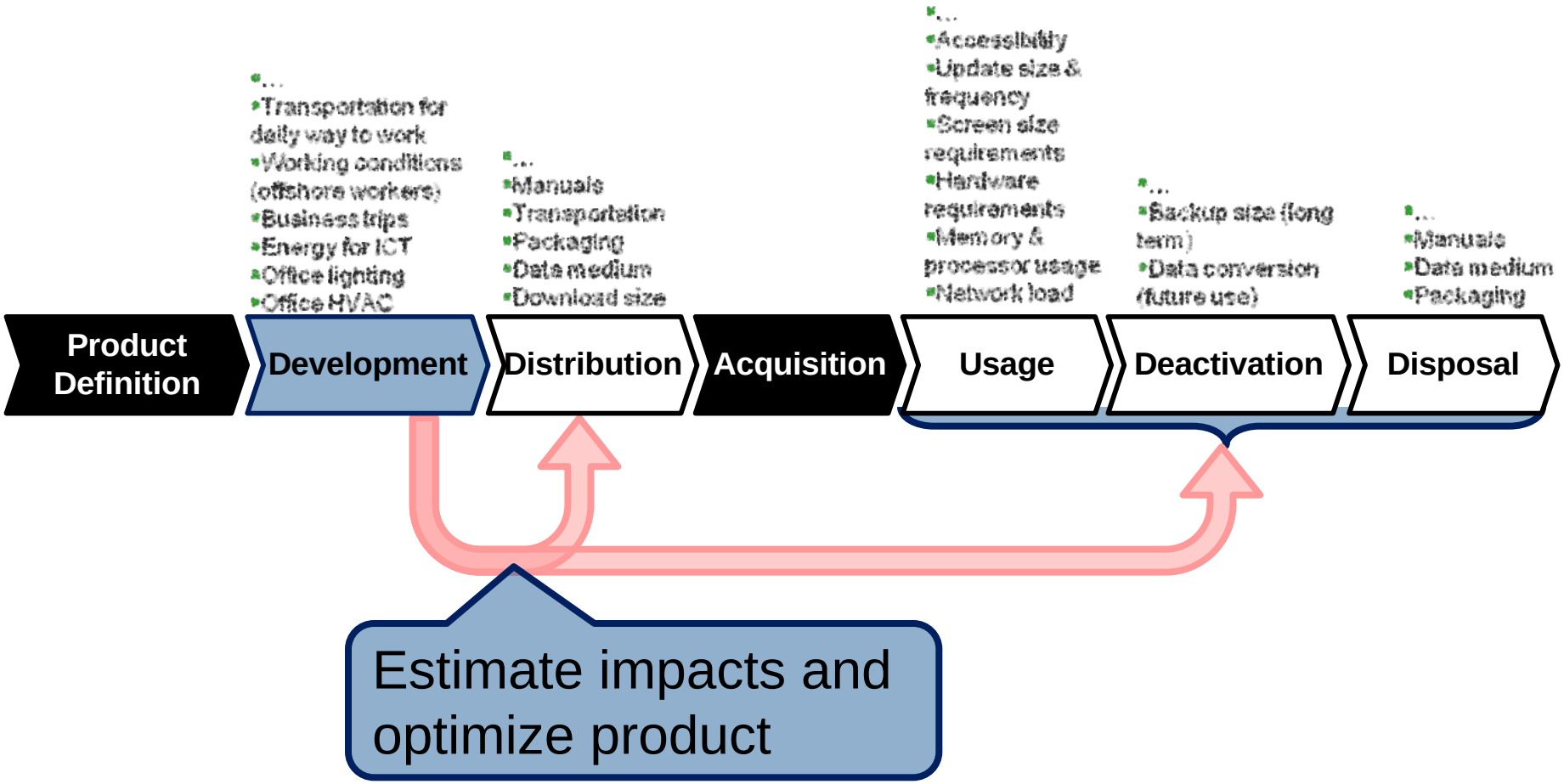
Sustainability Relevant Criteria

- …
- Accessibility
- Update size & frequency
- Screen size requirements
- Hardware requirements
- Memory & processor usage
- Network load

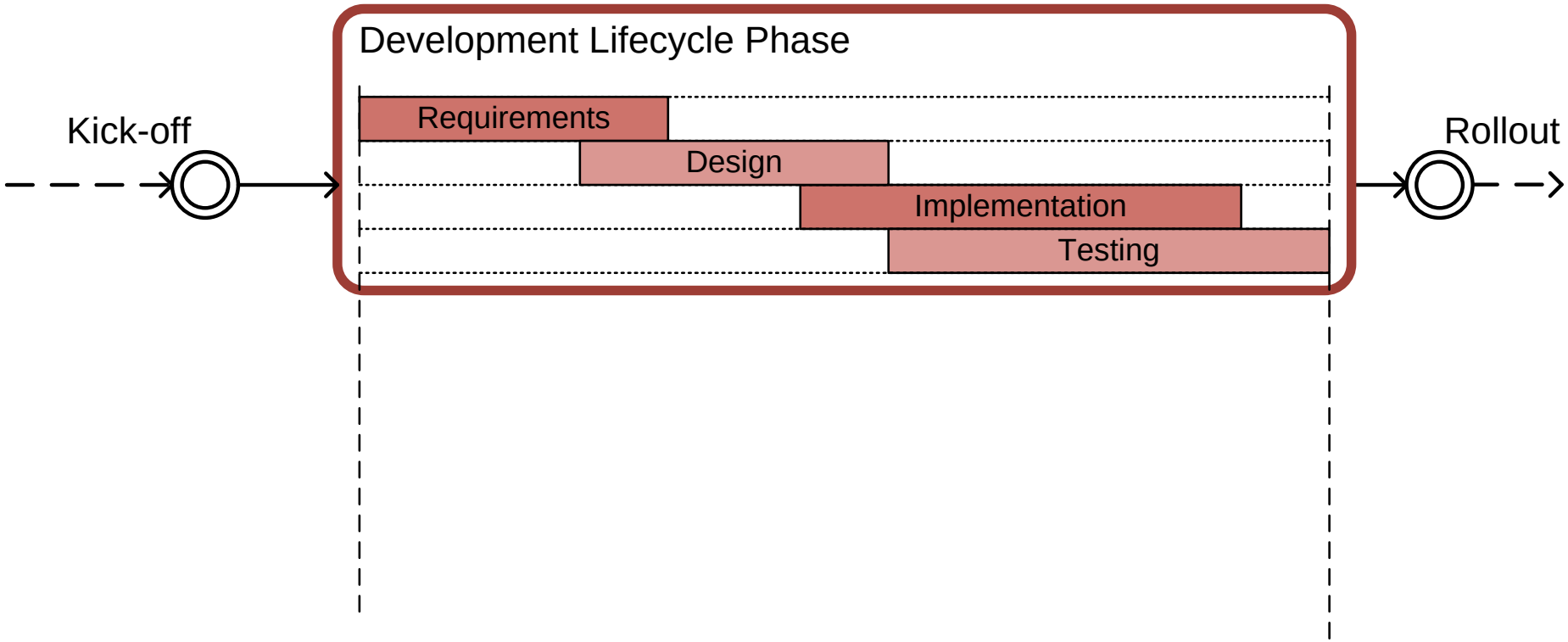
Starting Points for Activities



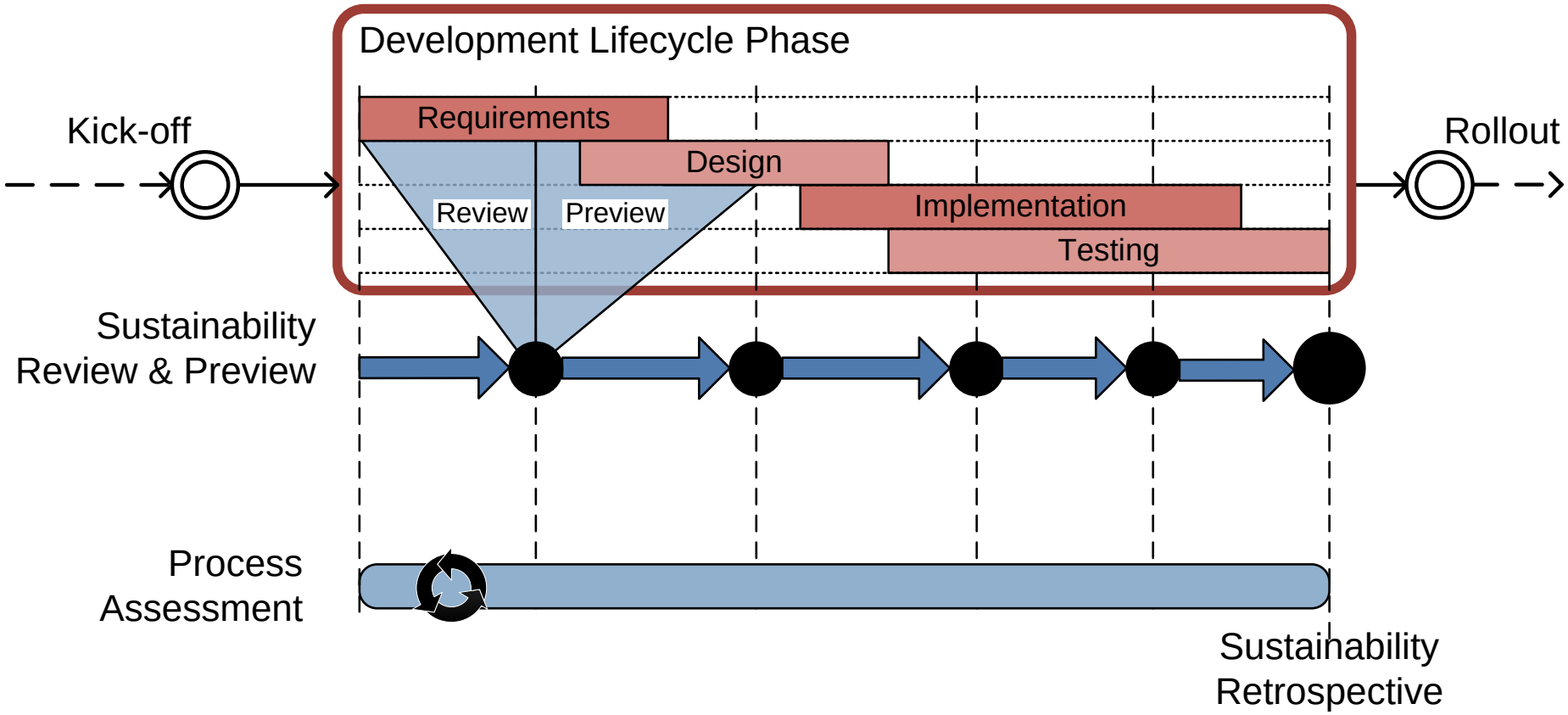
Starting Points for Activities



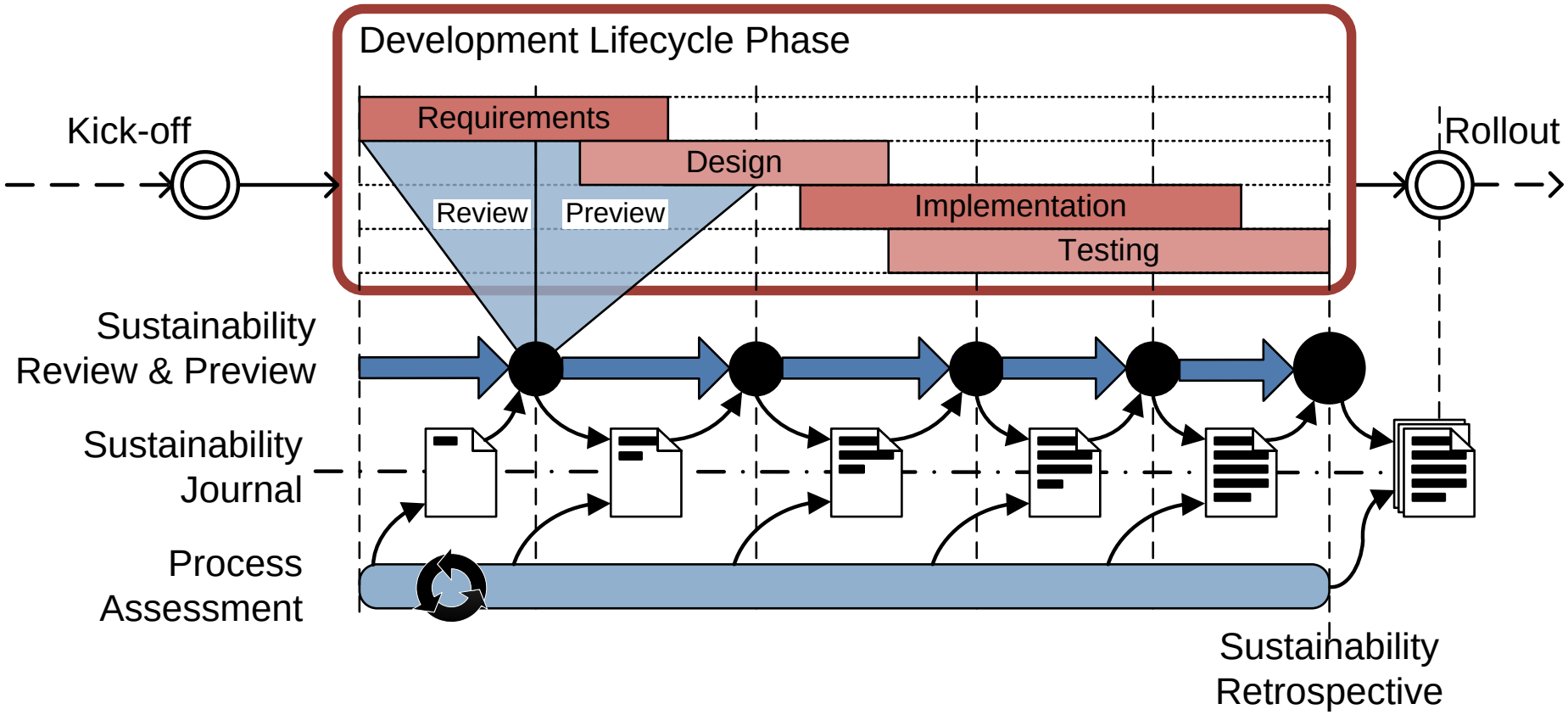
Overview of a GSE-Process Model



Overview of a GSE-Process Model



Overview of a GSE-Process Model



III. Influences of Software on Energy Consumption

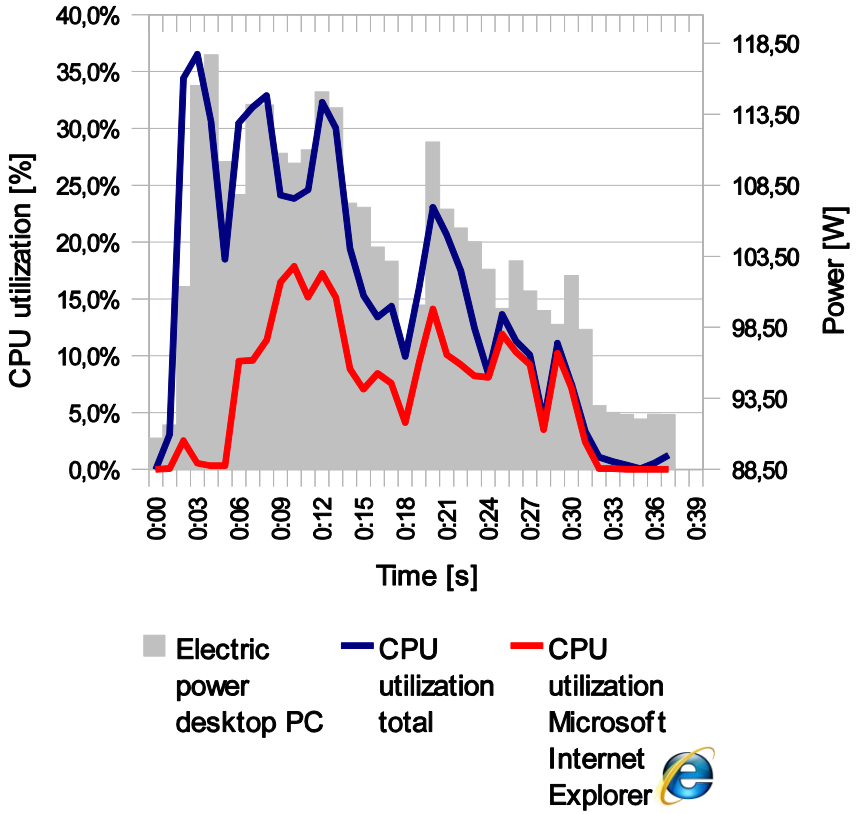
Software Selection and Configuration

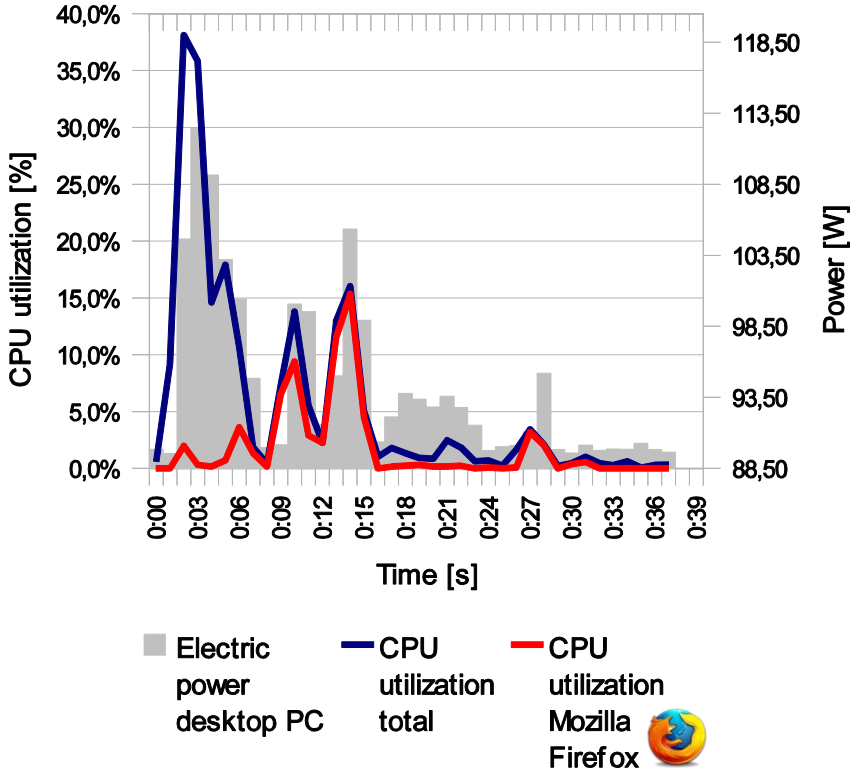
- How big is the influence of the software selection and configuration on the energy efficiency?
- Type of user
  - Private users
  - Professional users
- Typical end user test scenarios
  - Word processing
  - Browsing the web

Test Scenarios for Internet Browsers

- Comparing two browsers
  - Internet Explorer 8
  - Mozilla Firefox 3.6
- Measurement of the energy consumption for 10 minutes
- Websites with different kinds of content
  - Video Streaming YouTube
  - Knowledge Base (text and images) Wikipedia
  - Geographical Information System (JavaScript) Google Maps

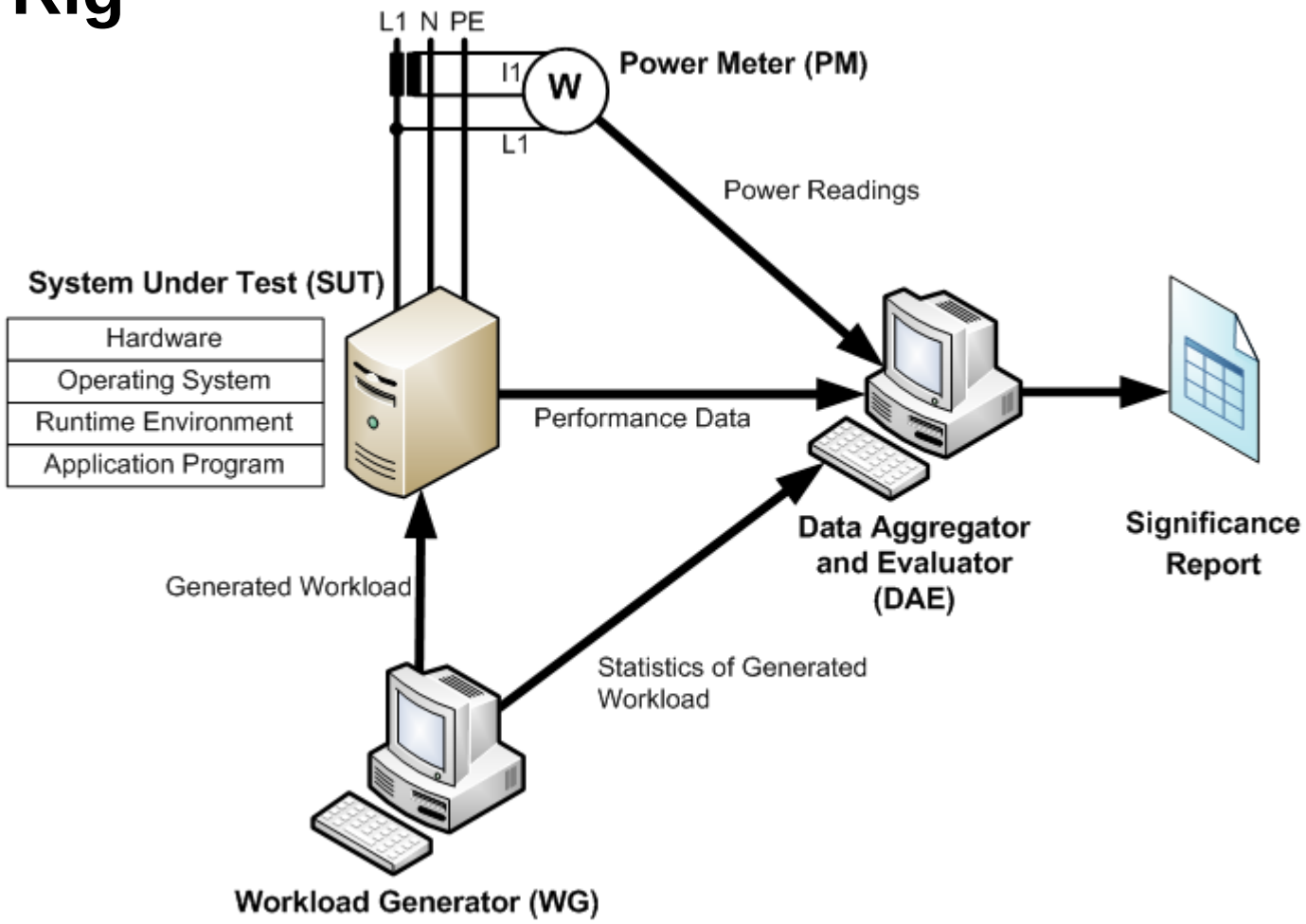
Results of the “Wikipedia” Test



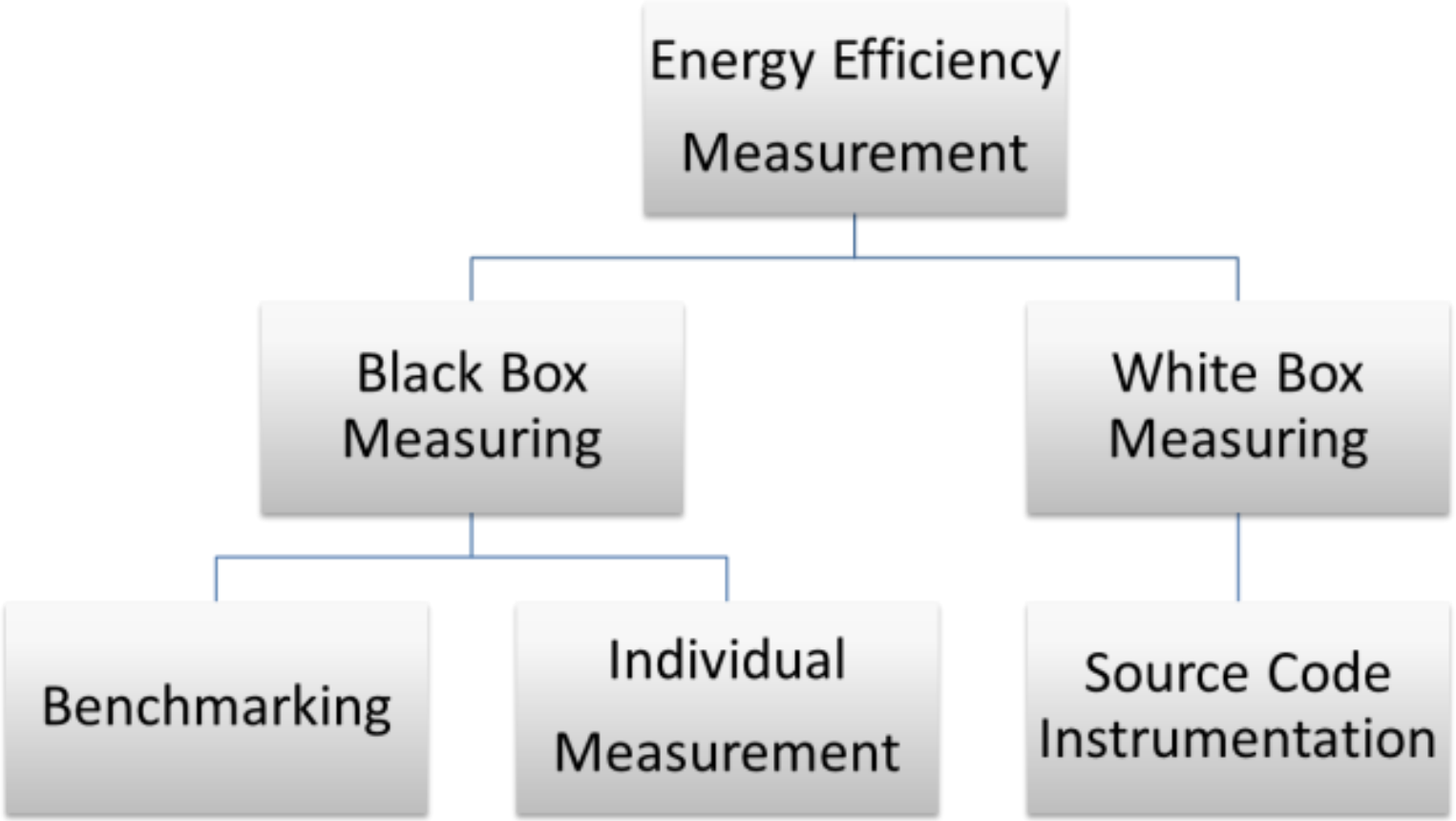


Consumption of resources of the knowledge base website

Test Rig


L1 N PE
I1
W
L1
Power Meter (PM)
Power Readings
System Under Test (SUT)
Hardware
Operating System
Runtime Environment
Application Program
Performance Data
Data Aggregator and Evaluator (DAE)
Significance Report
Generated Workload
Statistics of Generated Workload
Workload Generator (WG)

Measuring Options



Navigationsbereich

Measurement Overview | Measurement Details | System Under Test Details

System Under Test Details

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Application	Firefox 3.6.22
Compiler / Interpreter	-/-
Runtime Environment	32 Bit Subsystem
Operating System	Windows 7, 64 Bit, Build 7601
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 - Intel HD Graphics - Realtec RTL 8111DL Gigabit Ethernet NIC PCI-E - HDD Seagate 465 GB - Cooler Master 600W Silent Pro Gold power supply

Close | Delete

Import: Power Readings | Performance Readings | Task Log

Test Series

Label	Begin	End
01	16.09.2011 12:00:03	16.09.2011 12:08:55
02	16.09.2011 12:10:11	16.09.2011 12:19:02
03	16.09.2011 12:20:11	16.09.2011 12:29:03
04	16.09.2011 12:30:11	16.09.2011 12:39:02
05	16.09.2011 12:50:11	16.09.2011 12:59:03
06	16.09.2011 13:00:11	16.09.2011 13:09:02
07	16.09.2011 13:40:11	16.09.2011 13:49:01
08	16.09.2011 13:50:11	16.09.2011 13:59:01

Delete All Power Readings | Delete All Performance Readings | Delete All Task Log Items

Significance Report

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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 cache for HTML fragments)
Compiler/Interpreter: PHP 5.3.2-1Ubuntu4.9
Runtime Environment: Apache 2.2.14
Operating System: Ubuntu SMP 10.04 LTS (Linux 2.6.32-32-generic-pae)

Hardware: CPU: 2 Intel Xeon Dualcore CPU 2.40 GHz
RAM: 2GB
Board: Supermicro P4BP8-G2/P4DPE-G2
BIOS: Rev 1.2b
CD-ROM: ATAPI CD-ROM: Pioneer DVD-ROM ATAPI Model DVD 1068-1022

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	33,910 Wh
Average:	00:10:00	33,937 Wh
Standard Deviation:	00:00:00	0,163 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

2.

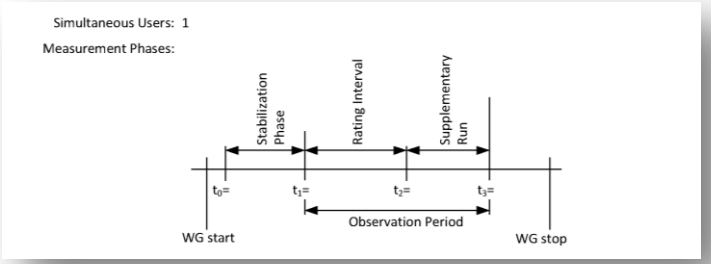
Application: joomla 1.5.23 (with hard disk cache for HTML fragments)
Compiler/Interpreter: PHP 5.3.2-1Ubuntu4.9
Runtime Environment: Apache 2.2.14
Operating System: Ubuntu SMP 10.04 LTS (Linux 2.6.32-32-generic-pae)

Hardware: CPU: 4 I
RAM: 2
Board: S
BIOS: Re
CD-ROM
ROM ATAPI Model DVD 1068-1022

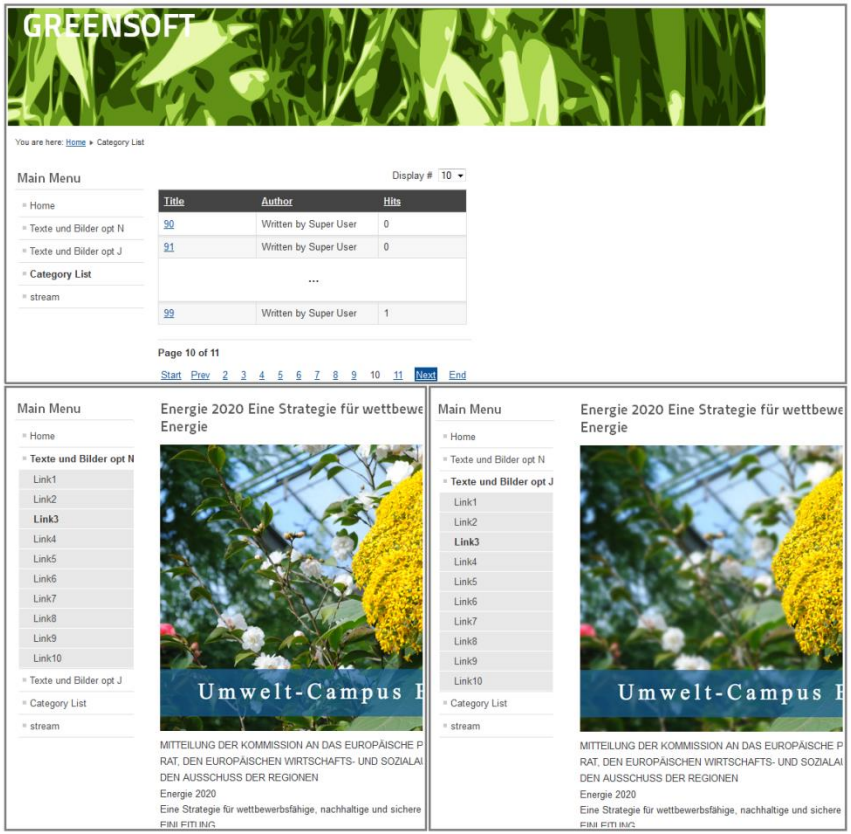
Significance Test (T-Test)

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



- 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

Scenarios and Workload Definition

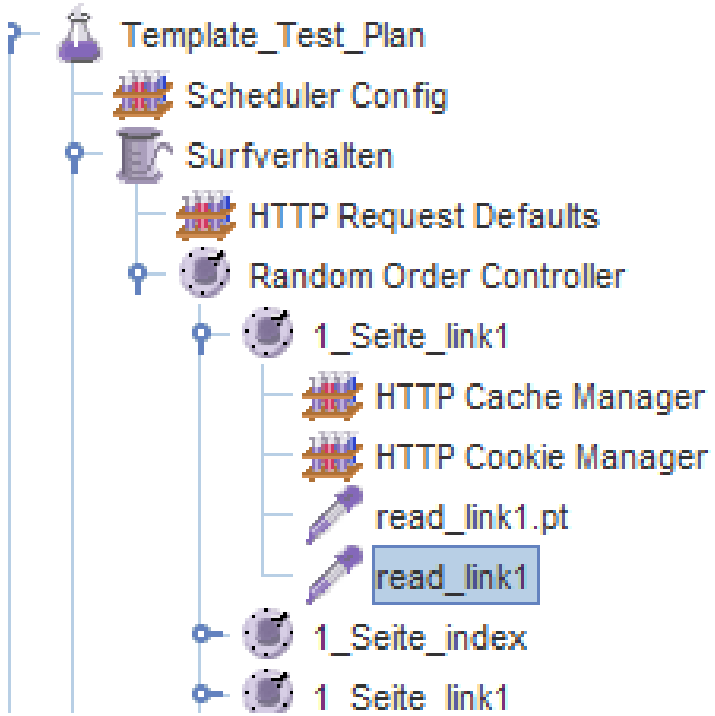
- Workload levels:
  - 10 % CPU load with 20 users
  - 30 % CPU load with 50 users
  - 50 % CPU load with 72 users
- Measurement experiements
  - 40 minutes for each SUT

  → Set up phase (2 minutes)

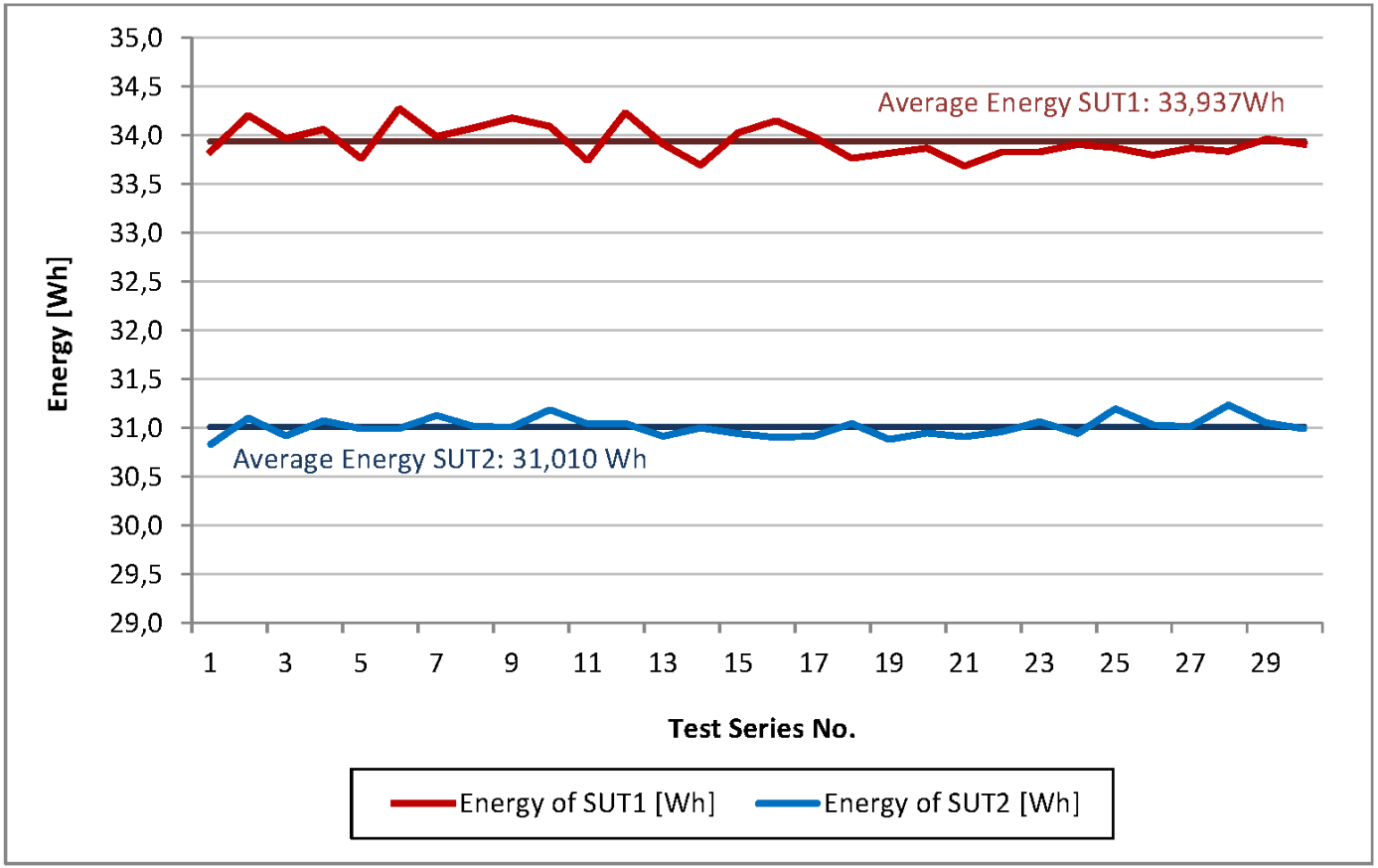
  → Stabilization phase (5 minutes)

  → Observation periode (30 minutes)

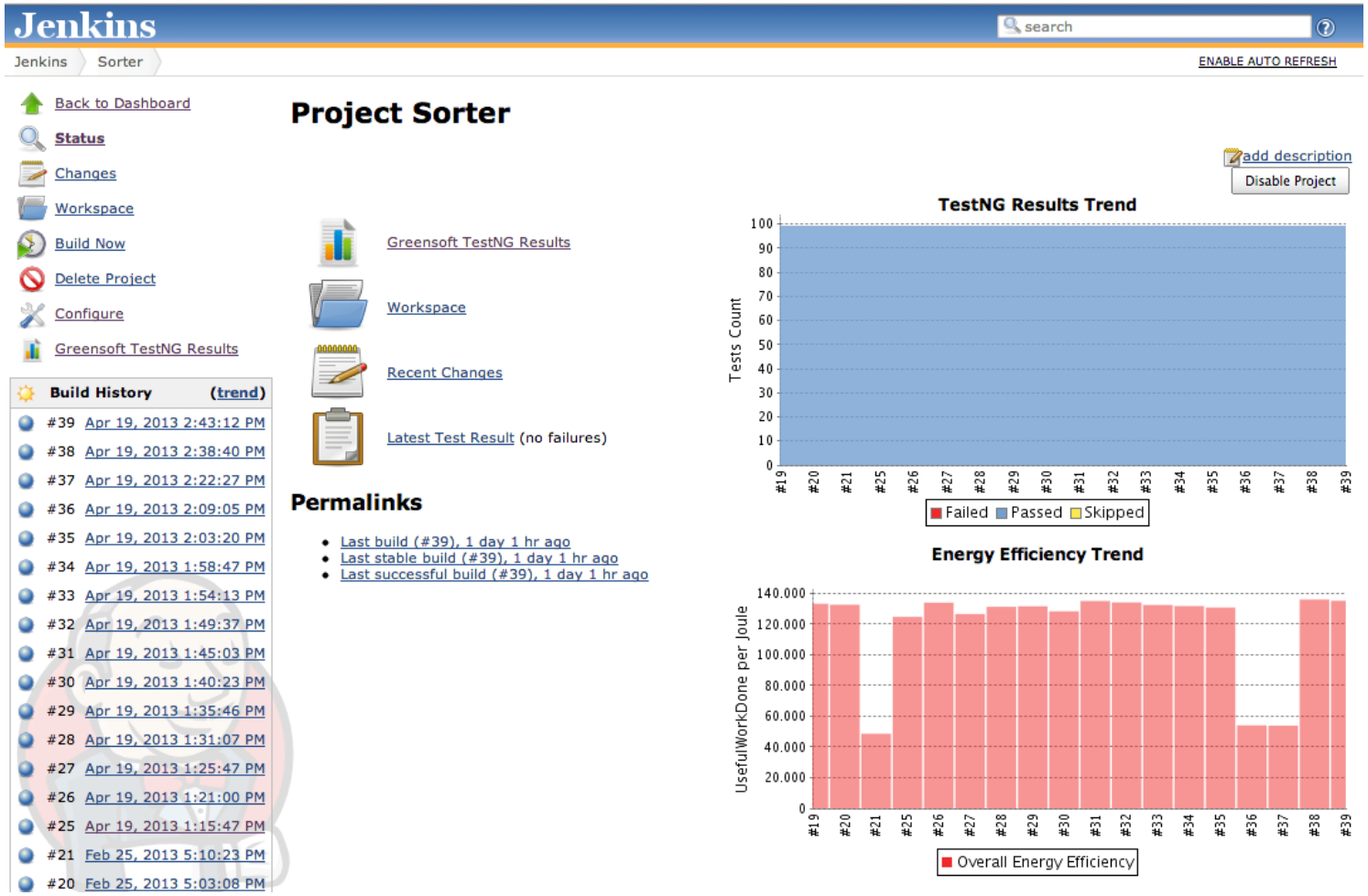
  → Supplementary phase (3 minutes)



Measuring Joomla: with vs. without HTML Caching



Integrating measurements into development process



Jenkins

search

Jenkins › Sorter › #37 › Greensoft TestNG Results › de.umweltcampus.uput.informatik.sort › de.umweltcampus.uput.informatik.sort.SorterUnsortedTest ENABLE AUTO REFRESH

- Back to Project
- Status
- Changes
- Console Output
- Edit Build Information
- Delete Build
- Git Build Data
- No Tags
- Greensoft TestNG Results
- Previous Build
- Next Build

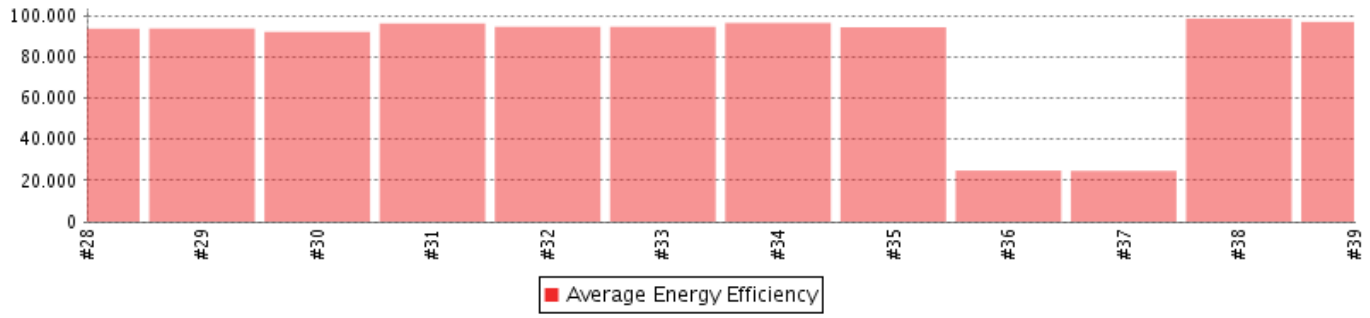
Class de.umweltcampus.uput.informatik.sort.SorterUnsortedTest

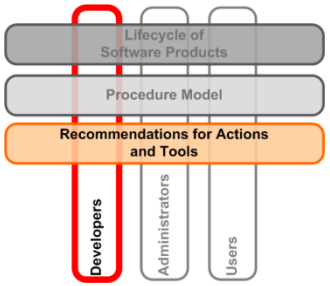
Energy Efficiency Report

Name	Total	Average	Standard Deviation
Duration	597.0 seconds	19.9 seconds	0.42
CPU Usage	0.55	0.55	0.05
Useful Work Done	300000000 Items	10000000 Items	0.0
Used Energy	12152.0 Joule	405.0 Joule	15.29
Energy Efficiency	24687.0 Items per Joule	24687.0 Items per Joule	912.29

Trend

Build	#28	#29	#30	#31	#32	#33	#34	#35	#36	#37
Items per Joule	93808.0	93896.0	92250.0	96339.0	94726.0	94726.0	96587.0	94488.0	24822.0	24687.0
Variation	+0%	+0.09%	-1.75%	+4.43%	-1.67%	+0%	+1.96%	-2.17%	-73.73%	-0.54%





CSS Optimization Hints in IDEs

corporate-style.css

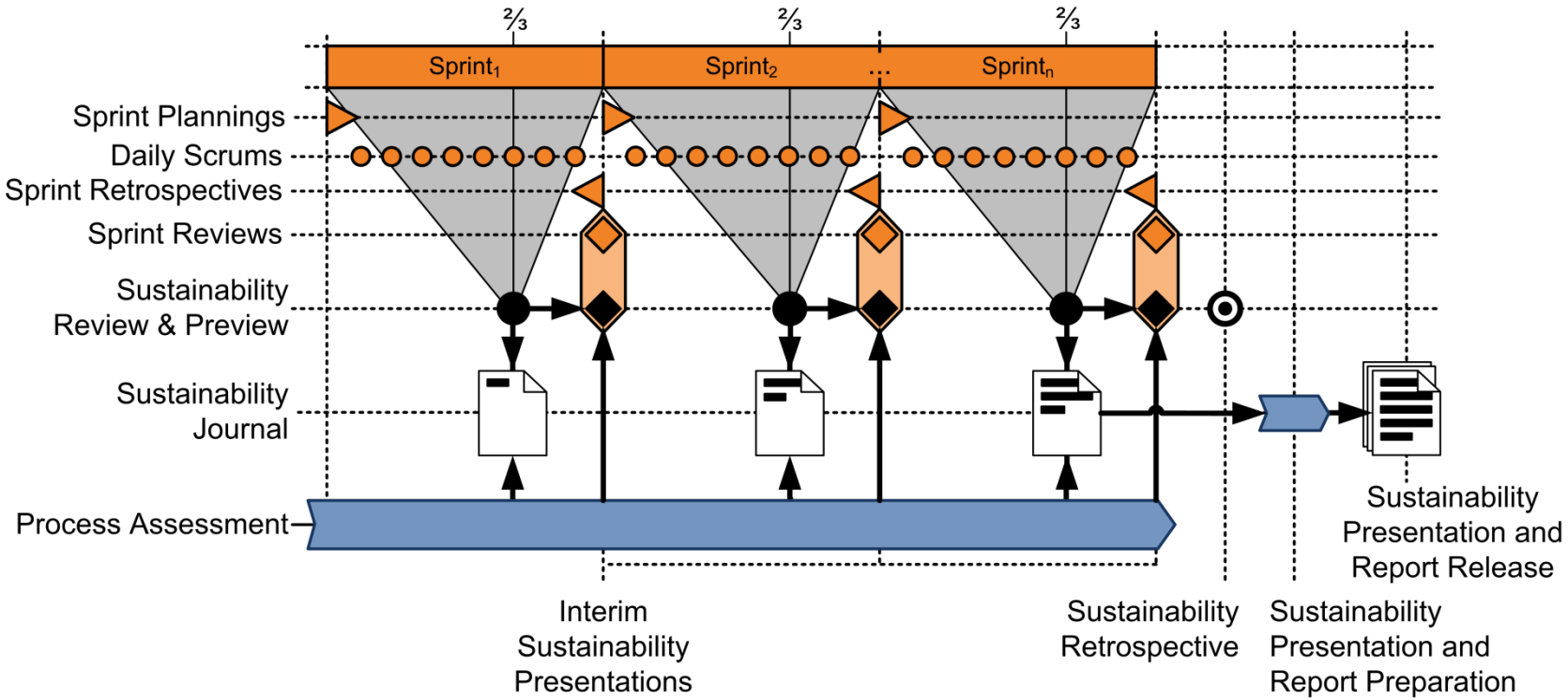
```
105 input[type=text]
106 {
107     color:#000000;
108     background-color:#FFFFFF;
109     border-width:0px;
110 }
111
112
```

Problems | Tasks | Console

1 error, 3 warnings, 0 others

Description	Resource	Path	Lo
Errors (1 item)			
Warnings (3 items)			
Optimise colour: Change "#000000" to "#000"	corporate-st...	/StudentAssistan...	lin
Optimise colour: Change "#FFFFFF" to "#FFF"	corporate-st...	/StudentAssistan...	lin
Optimise number: Change "0px" to "0"	corporate-st...	/StudentAssistan...	lin

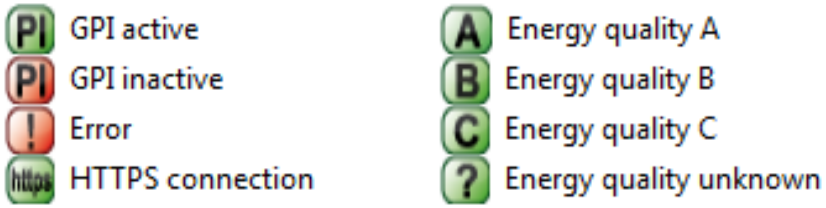
Integrating these issues e.g. into Scrum



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!

GreenSoft
Green Software Engineering

Feel free to contact us:

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