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Öko-Institut e.V.
Institut für angewandte Ökologie
Institute for Applied Ecology

Energy Consumption of Software

Results of the research project „Development and Application of Criteria for resource-efficient Software Products with Consideration of existing Methods”

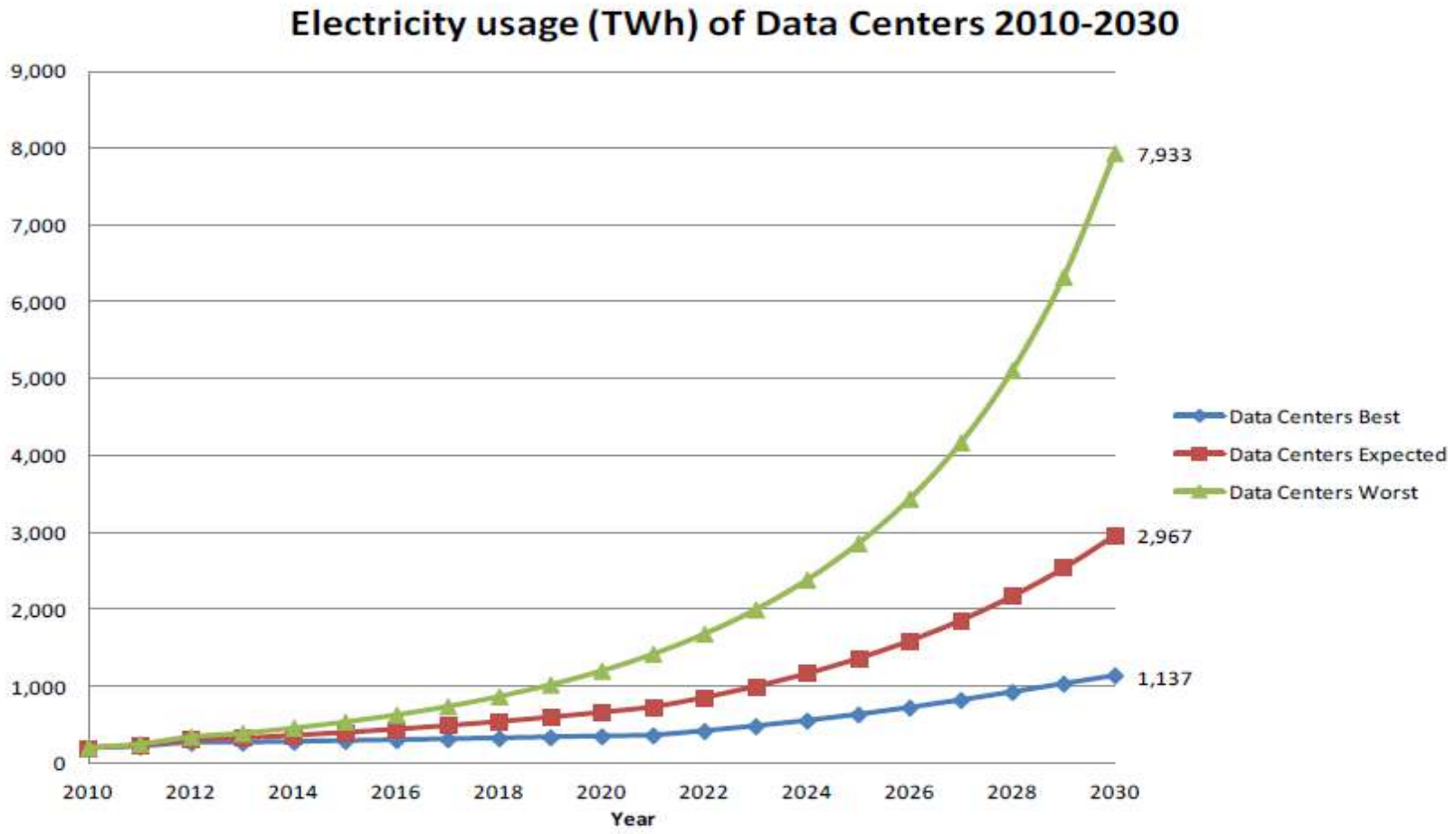
Jens Gröger, Oeko-Institut e.V.
13th OERC Energy & Climate Change Symposium 2019
Dunedin, 22 November 2019

Short Introduction into Oeko-Institut

- Oeko-Institut is a leading European research and consultancy institute working for a sustainable future
- Founded in 1977 as a non-profit association (tax reducible)
- The aim of our work is to contribute to the preservation of environment and of natural resources
- Offices in Freiburg, Darmstadt and Berlin
- 170 employees, 70% researchers
- Turnover 2018: 16 million Euro
- Clients: European Union, national and state-level ministries, companies, foundations and non-governmental organizations

Significance of Hardware, Software and Data Processing

Data centre energy usage



Forecast:
Global electricity demand:
2030: 28.000 TWh/a

Share of electricity used by data centres 2030:

- ▲ Worst: 28%
- ■ Expected: 11%
- ♦ Best: 4%

Source: Andrae, A., Edler, T.: On Global Electricity Usage of Communication Technology: Trends to 2030; Challenges 2015

Bitcoin energy consumption

15% of 500 TWh

Source: https://digiconomist.net/bitcoin-energy-consumption

Software bloat

"Software is getting slower more rapidly than hardware becomes faster."

Niklaus Wirth, "A Plea for Lean Software", Computer 28, 1995

Comparison of Microsoft Windows minimum hardware requirements (for x86 versions)

Windows version	Processor	Memory	Hard disk
Windows 95[8]	25 MHz	4 MB	~50 MB
Windows 98[9]	66 MHz	16 MB	~200 MB
Windows 2000[10]	133 MHz	32 MB	650 MB
Windows XP[11] (2001)	233 MHz	64 MB	1.5 GB
Windows Vista[12] (2007)	800 MHz	512 MB	15 GB
Windows 7[13] (2009)	1 GHz	1 GB	16 GB
Windows 8[14] (2012)	1 GHz	1 GB	16 GB
Windows 10[15] (2015)	1 GHz	1 GB	16 GB

x 80

x 250

x 320

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

Research Project

Development and Application of Criteria for resource-efficient Software Products with Consideration of existing Methods

Research Project

Development and Application of Criteria for resource-efficient Software Products with Consideration of existing Methods

- Client: German Federal Environment Agency
- Published: December 2018

Processing by research group

- **Oeko-Institut e.V.**, Products and Material Flows Division
  - Expertise in the sustainability analysis of ICT devices,
    Development of award criteria for eco-labels
- **University of Zurich**, Computer Science and Sustainability
  - Expertise in life cycle assessment of ICT devices and infrastructure
- **Trier University of Applied Sciences**, Environmental Campus Birkenfeld,
  Institute for Software Systems in Economy, Environment and Administration
  - Expertise in evaluation and software,
    Green Software and Green Software Engineering

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Universität Zürich[UZH]

HOCHSCHULE TRIER
Umwelt-Campus Birkenfeld

Research Questions

- Is there a **connection** between software and resource consumption?

- Is it possible to define **criteria** for assessing the resource use of software?

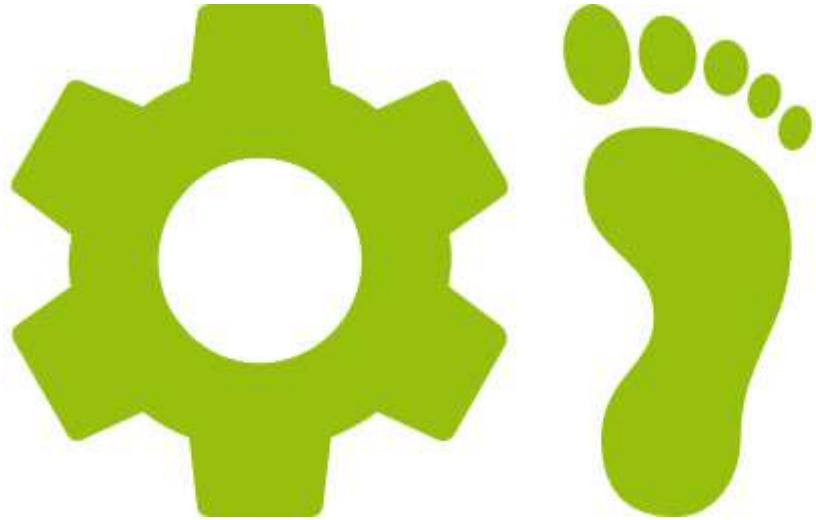
- Are such criteria suitable for **comparing** different software products?

- Can **minimum requirements** be defined that describe resource-efficient software?

Most important Results

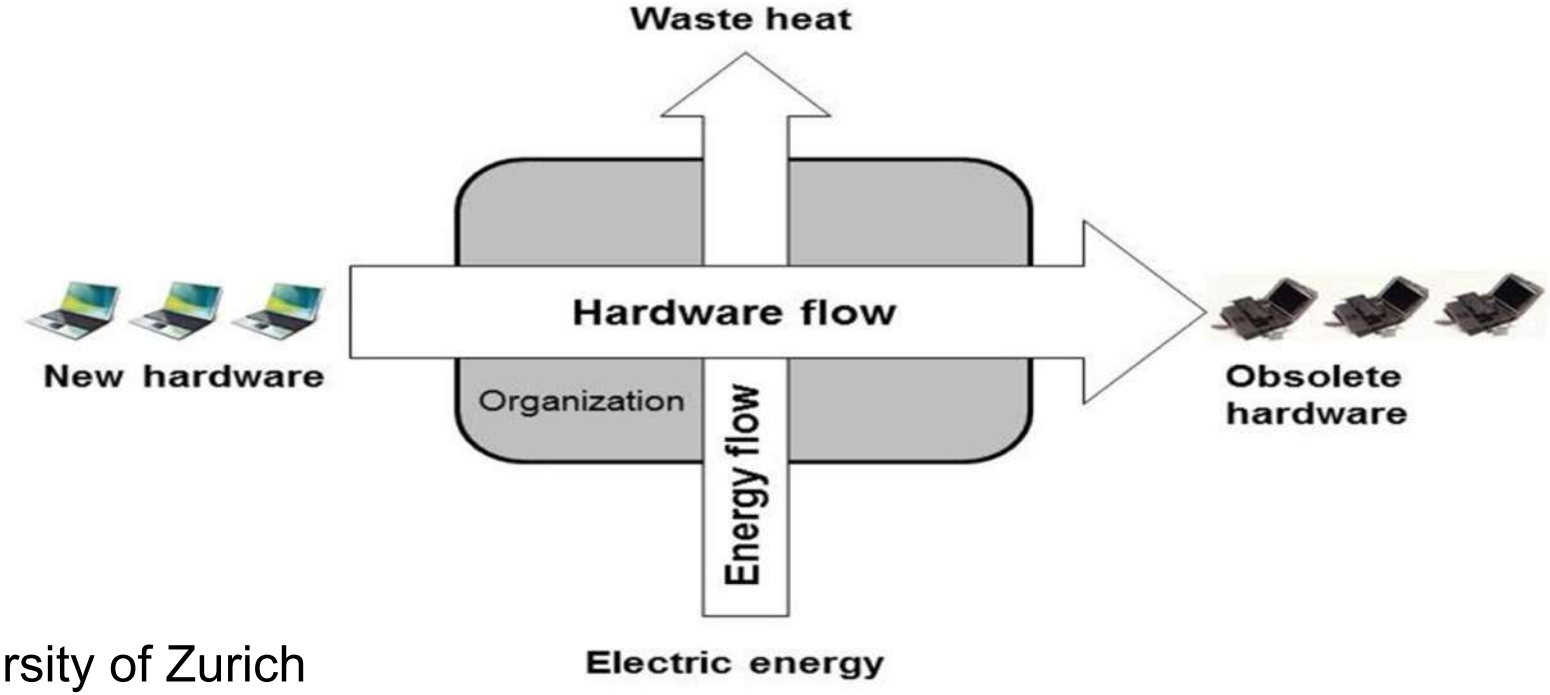
- Software is responsible for **energy consumption** and **hardware usage** and can contribute to hardware obsolescence.
- A **set of criteria for** sustainable software was developed which is suitable for the assessment and optimisation of software.
- The application of the criteria catalogue shows **clear differences** between different software products.
- It was possible to **identify criteria** that are suitable for an eco-label for software.

Relationship between Software and Resource Consumption



Energy and Hardware Consumption

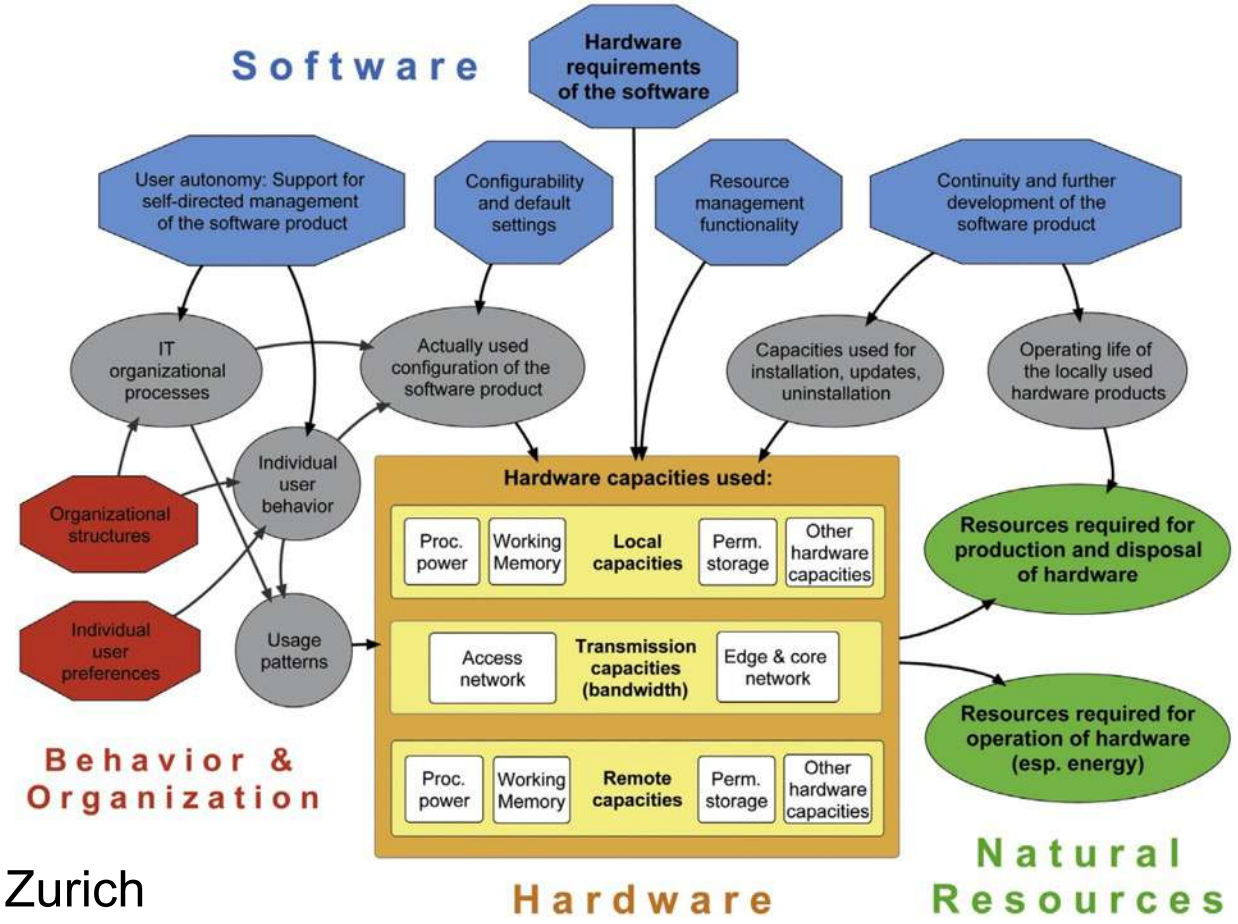
- Two essential flows caused by the use of a software product:
  - Flow of energy through the hardware running the software (electricity to waste heat)
  - Flow of hardware through an organization (company, office, data center, administration) using it (new hardware to electronic waste)



Source: University of Zurich

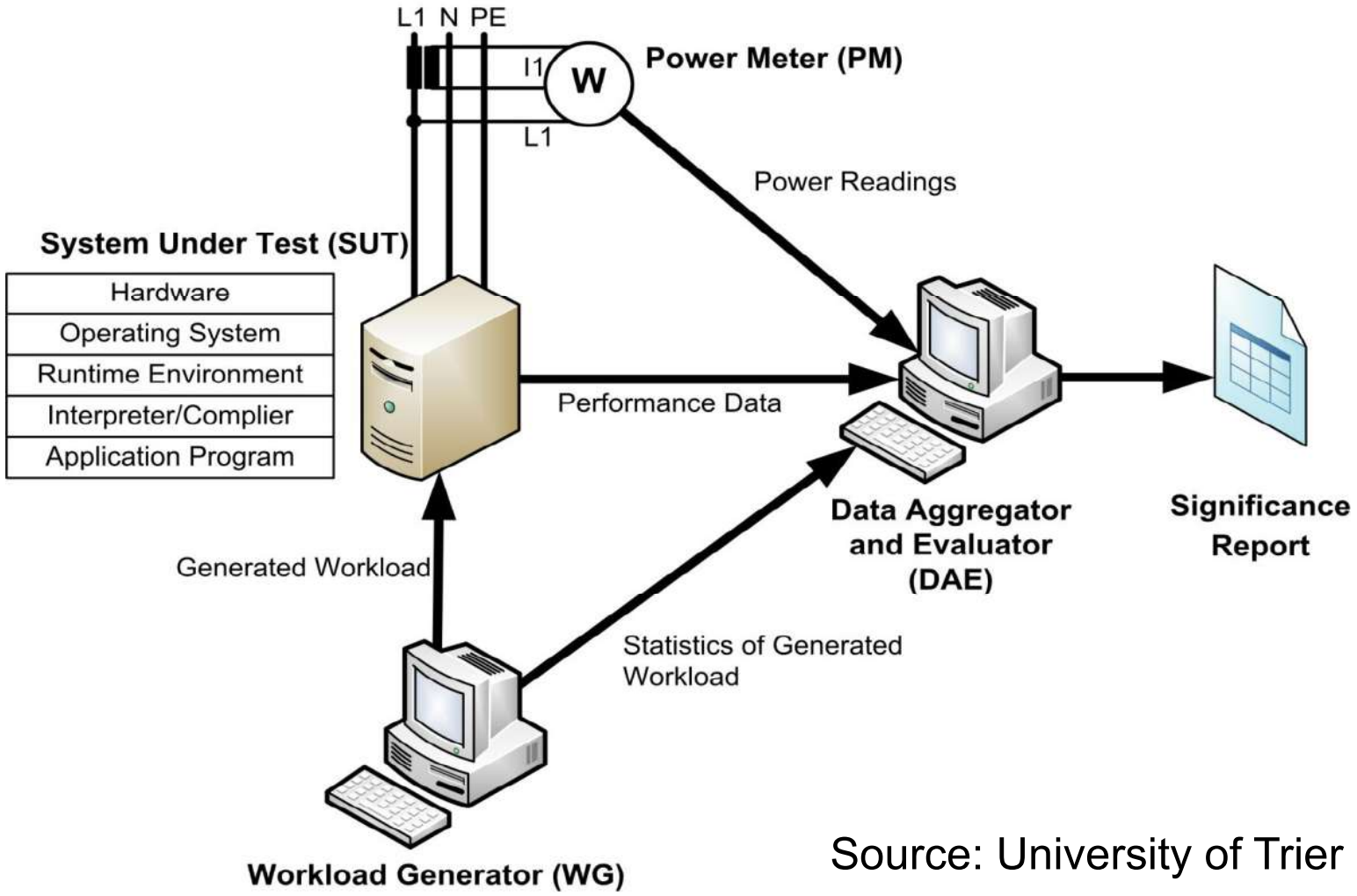
Causal Chain Model for Software and Resources

The model describes the causal chains leading from software properties **(blue)** to the natural resources required for using the software **(green)**.



Source: University of Zurich

Measurement Setup



Source: University of Trier

Further requirements to assess software

- Definition of a **reference system for** carrying out the measurements (System Under Test)
  - Resettable to a "clean" state (installation of a hard disk image before each measurement)
- Definition of a **standard usage scenario** for the application of the software
  - Simulation of a realistic use of the software
  - Interaction with the user
  - Processing of tasks for which the software was developed
- Operation of the software via a **load driver** without burdening the System Under Test by the load driver software itself
- Multiple, repeated measurements to avoid errors

Software product groups investigated in the project

	product group	architecture	products
1	Word processing	Local application	Two word processing programs were selected (TVP1 and TVP2). TVP1 is a proprietary product, TVP2 is open source.
2	Browser	Application with remote processing	Three Internet browsers were selected (B1, B2 and B3). B1 and B2 are open source, B3 is proprietary.
3	Content Management System	Application with remote processing	Three CMS (CMS1, CMS2 and CMS3) were selected. All CMS are open source.
4	Database	server service	Three database systems (DB1, DB2 and DB3) were selected. DB1 and DB2 are open source, DB3 is proprietary.

Standard usage scenarios

word processing program

1. Edit all text
2. Insert & update table of contents
3. Customize view
4. Add & edit content
5. Create PDF
6. Save

browser

1. Read/write e-mail
2. Watch Youtube video
3. Visit our online shop
4. Bookmark this page
5. Install Add-on
6. Download file

CMS

1. Reply to comments
2. Create new page
3. Publish all pages
4. Upload PDF files
5. Link PDF files
6. View page

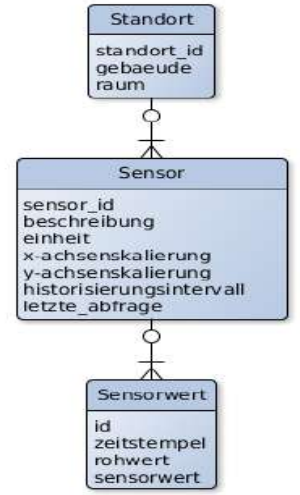
Additional: Load generation for
Simulation of visitors

database

Schema already exists

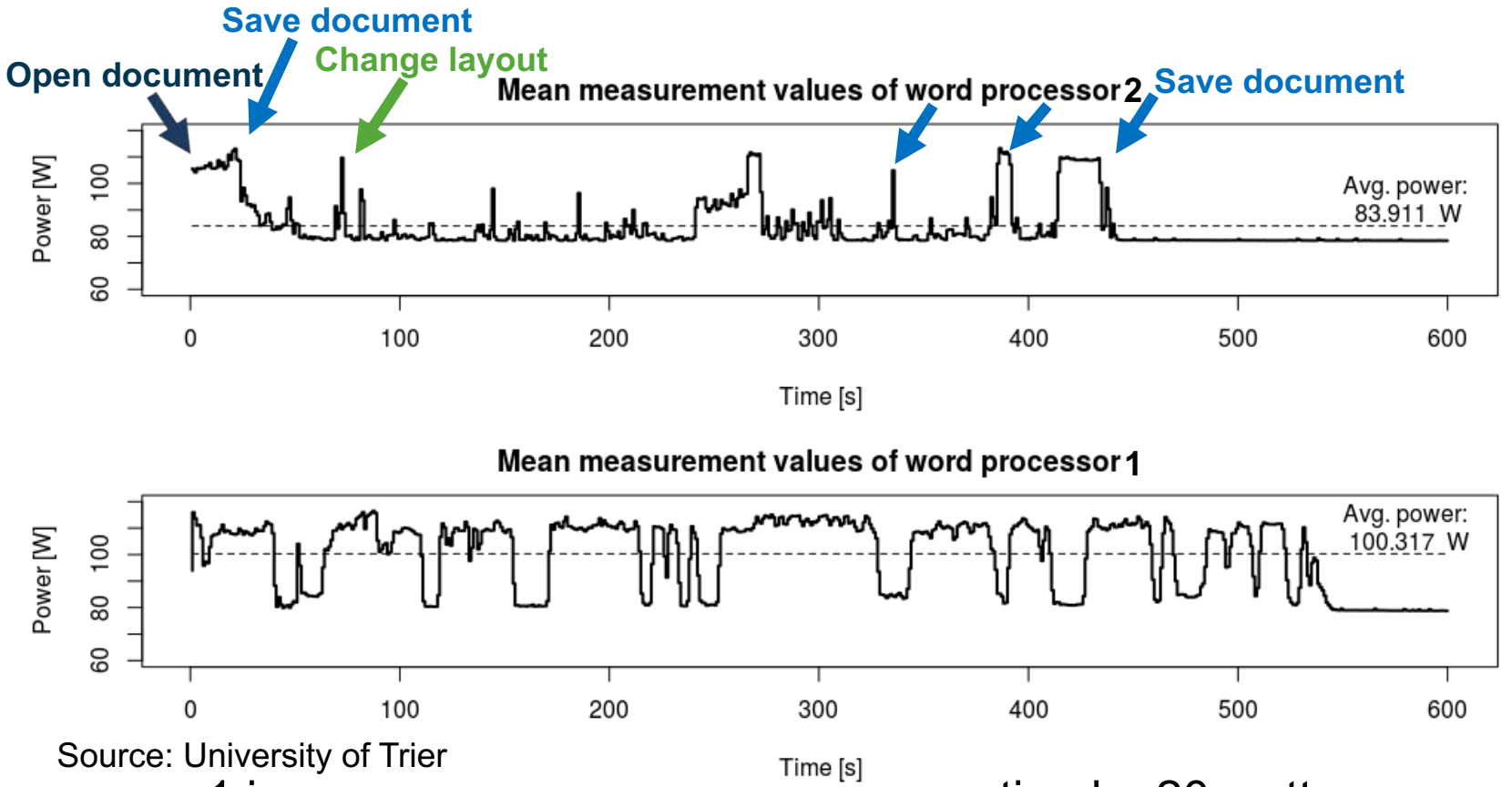
1. enter data
2. Read data
3. Change data
4. Delete data

230 passes per function,
120,000 accesses per pass



Example of a measurement cycle

- Measurement of **word processing software** usage over 10 minutes

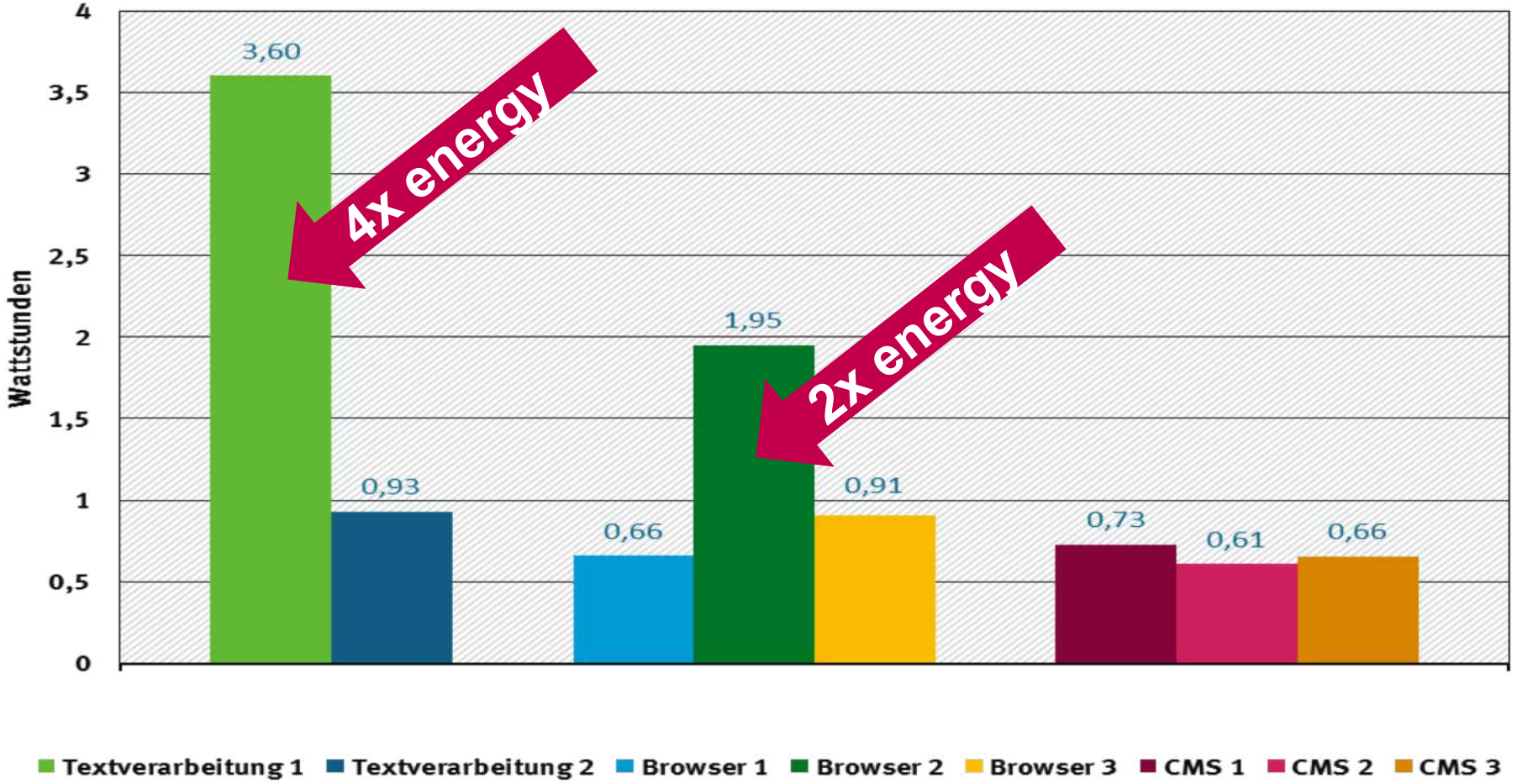


Source: University of Trier

→ Word processor 1 increases average power consumption by 20 watts

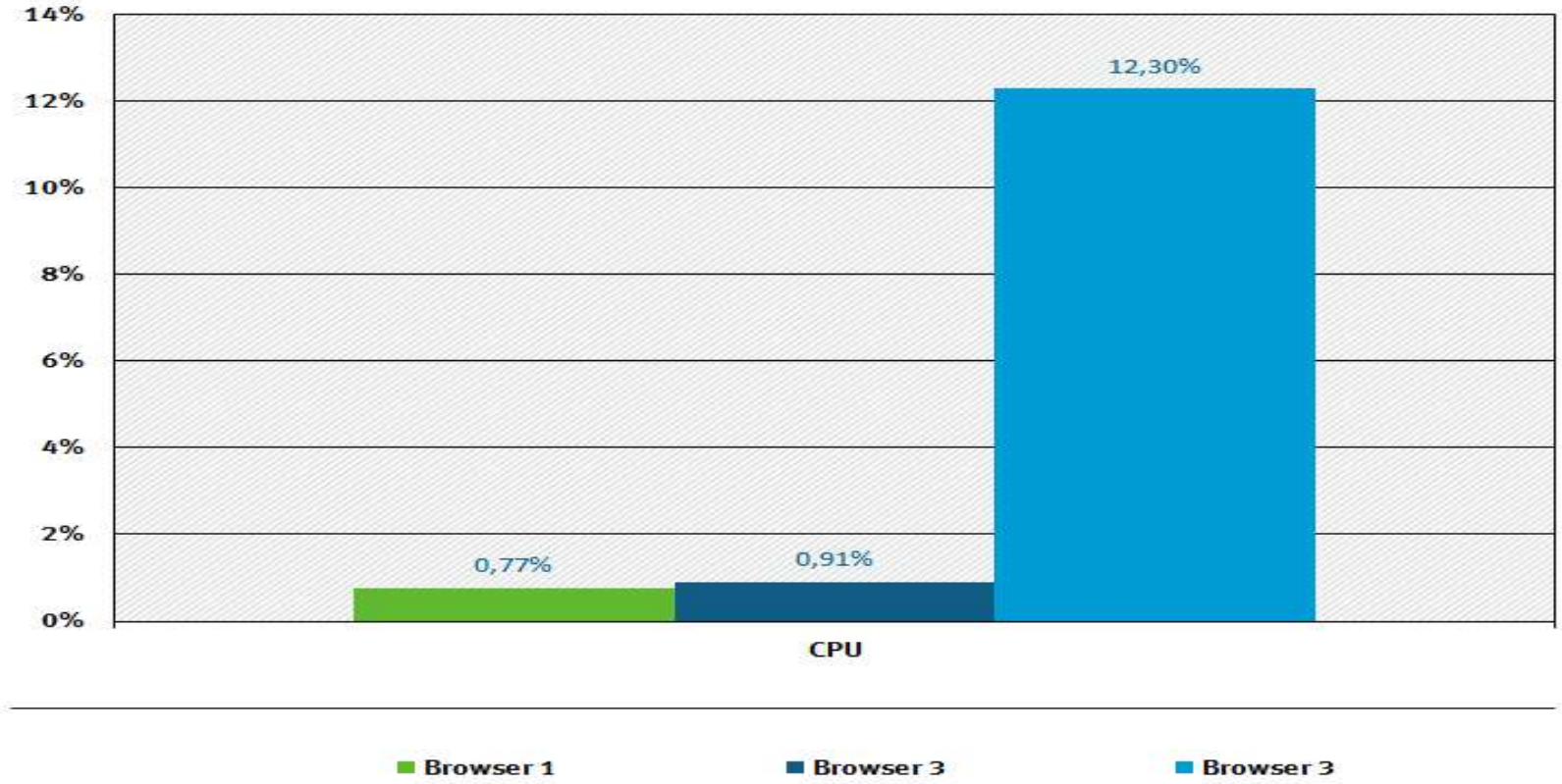
Exemplary measurement results usage scenario

- Energy consumption during execution of a standard usage scenario



Exemplary Measurement Results Idle Mode

- Hardware utilization (CPU) in idle mode of three internet browsers



→ Browser 3 needs ~12 times more CPU power in idle mode

Set of criteria for Sustainable Software Design

Set of criteria for Sustainable Software Design

Criterion
1 Resource efficiency
1.1.2 Minimum system requirements and resulting hardware requirements (incl. peripheral devices)
1.1.3 Hardware utilization in idle mode assuming a standard configuration
1.1.4 Hardware utilization during normal use assuming a standard configuration and a standard usage scenario
1.2 Energy efficiency
2 Potential useful life of hardware
2.1 Backward compatibility
2.2 Platform independence and portability
2.3 Hardware sufficiency
3 User autonomy
3.1.1 Transparency of data formats and data portability
3.1.2 Transparency and interoperability of the programs
3.1.3 Continuity of the software product
3.2.1 Uninstallability of programs
3.4.1 Offline capability
3.5.1 Comprehensibility and manageability of product documentation, licensing conditions and terms of use

→ http://green-software-engineering.de/en/kriterienkatalog-v01/download.html

Further development

- Application of the criteria for sustainable software in the **public procurement** of standard software and in the commissioning of software programming services
  https://www.umweltbundesamt.de/publikationen/leitfaden-zur-umweltfreundlichen-oeffentlichen-21

- **Voluntary application** of the set of criteria by software developers to impove their products

- Development of the German eco-label **Blue Angel**
  for sustainability software products
  (to be published in Jan 2020):
  https://www.blauer-engel.de/en/companies/basic-award-criteria

- Awarding sustainable software and labelling with a "**Sustainability Footprint**"
  (XML file for software with software properties)

- Assessment of **software driven obsolescence** of hardware, caused by rising software requirements or missing compatibility (derivation of political recommendations)

Thank you very much for your attention!

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From 08/2019 to 06/2020
as a guest scientist:
Centre for Sustainability
University of Otago

More information about this project:
https://www.sciencedirect.com/science/article/pii/S0167739X17314188