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Institut für angewandte Ökologie
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ECO·DIGIT

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Methods to determine the environmental footprint of software – on the way to standardization – Part 2: Allocation

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Challenges in software life cycle assessment

- Software applications usually run on **shared IT infrastructures** (e.g. computers, servers, cloud infrastructure) that are also used by other applications.
- The **manufacturing effort** and the **environmental impacts during the use phase** must be appropriately distributed (allocated) among the various software applications.
- Standardised **allocation rules** must therefore be established.



Software	GWP
App 1	??
App 2	??
App 3	??
Sum	e.g. 100 kg CO ₂ e

Method for allocating environmental impacts

- The method we developed in the **ECO·DIGIT** project allows the accounting of software that runs on shared IT infrastructures (e.g. cloud applications, containers, virtual machines)
 - Environmental impacts are allocated using ‘Basic Digital Resources’:
 - Computing power (compute)  (e.g. server, user device)
 - Memory performance (memorize)  (e.g. RAM)
 - Storage capacity (store)  (e.g. storage system, HDD, SSD)
 - Data transfer (transfer)  (e.g. switch, router, mobile communications)
 - Every **computer provides** a certain amount of basic digital resources over its lifetime
 - Every piece of **software uses** a certain amount of basic digital resources to be executed
- The environmental impact of manufacturing and using the hardware can be allocated to different applications by using the ‘Basic Digital Resources’ as a distribution key

Example: Running 3 Software Apps on a Raspberry Pi 4 Model B



WiFi network

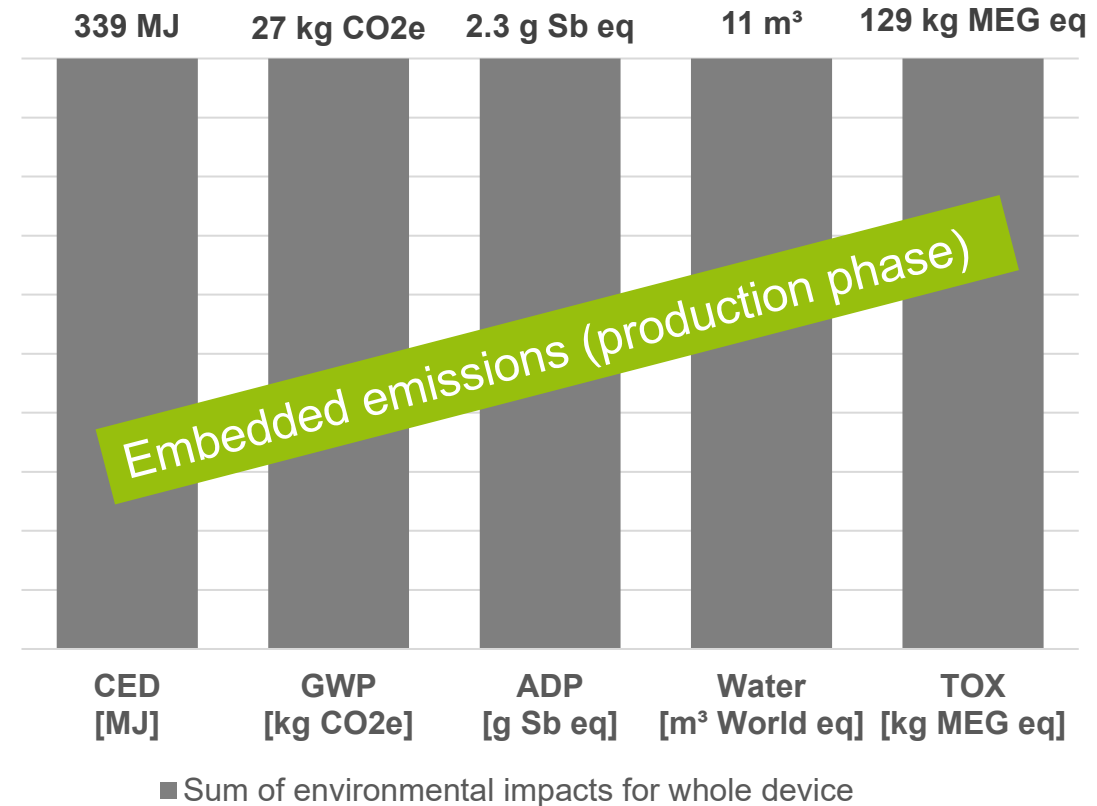
Client



- Generation of a continuous video stream using 3 different software applications:
 - App 1: ecopower.py
 - App 2: ffmpeg
 - App 3: motion
- Delivery of the video stream via the local network
- Receiving the video stream on a client computer running VLC (not part of the measurement and life cycle assessment)

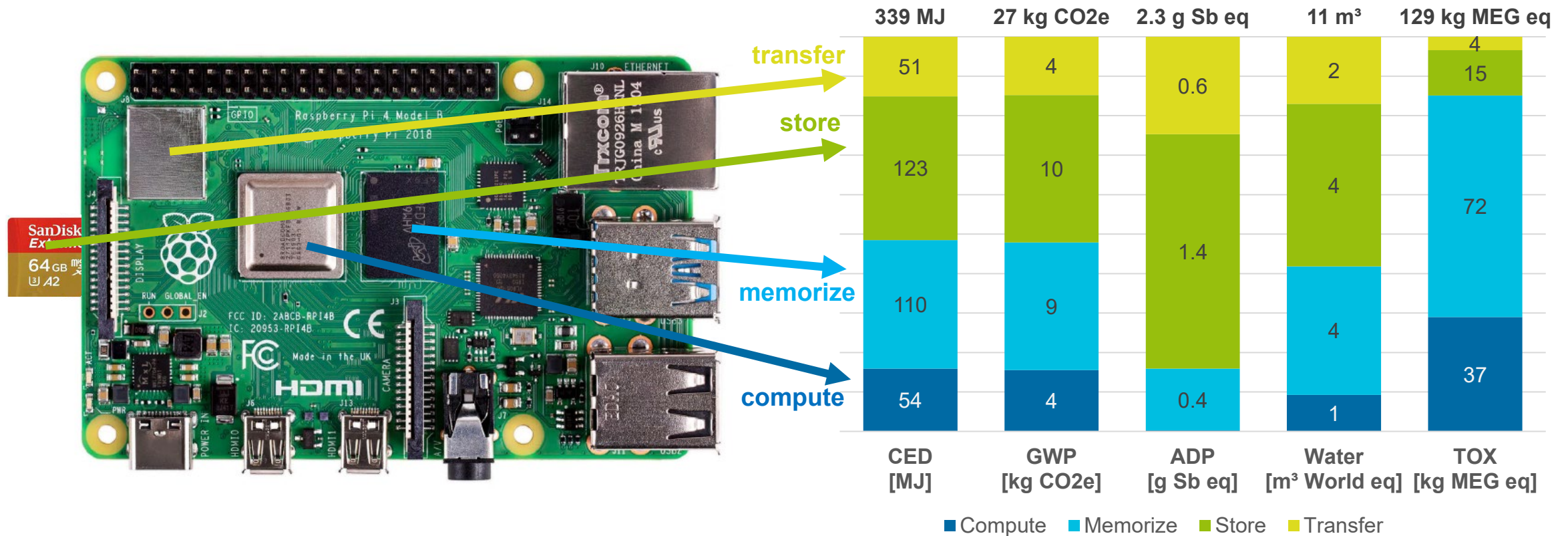


Environmental impact of the Raspberry Pi 4 Model B (*embedded emissions*)



- *Embedded emissions*: Environmental impacts associated with the manufacture of hardware
- *Use phase emissions*: Environmental impacts arising from the use of hardware, in particular from its electric energy consumption

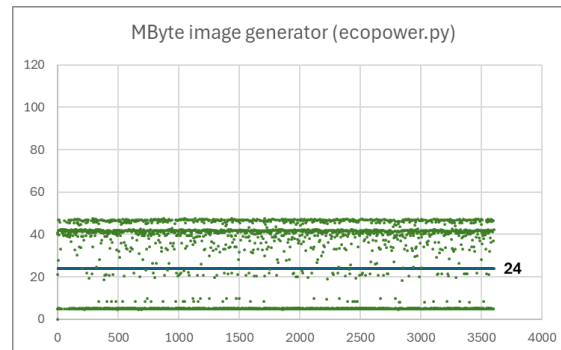
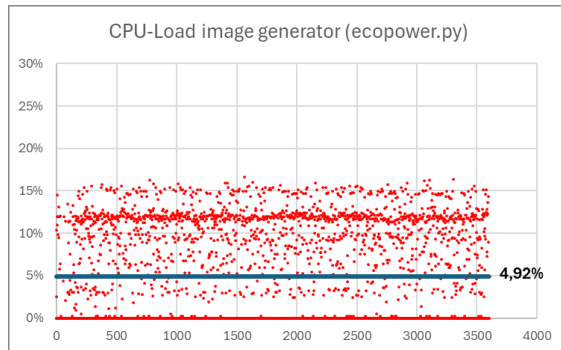
Differentiation of environmental impacts according to Basic Digital Resources



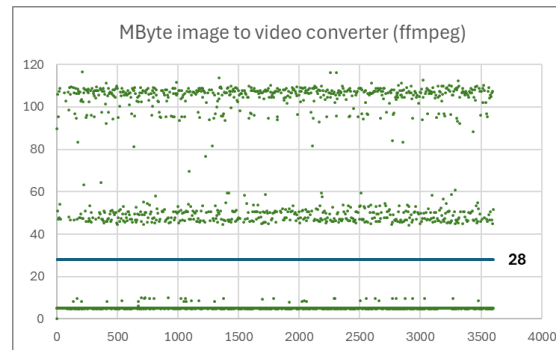
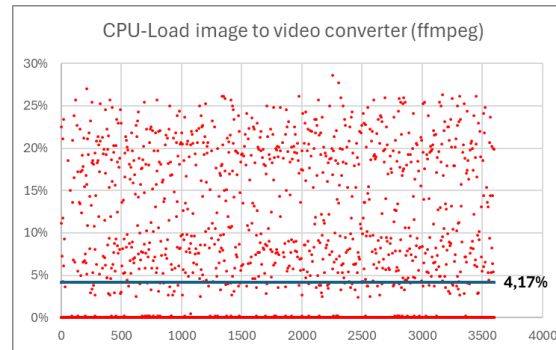
- Breakdown of environmental impact categories into the four „Basic Digital Resources“
- All other components (e.g. circuit board, power supply, heat sink) are distributed proportionally
- This breakdown is also applied to impacts during the use phase (esp. energy consumption).

Example: Measuring hardware utilisation with logging tools for 1 hour

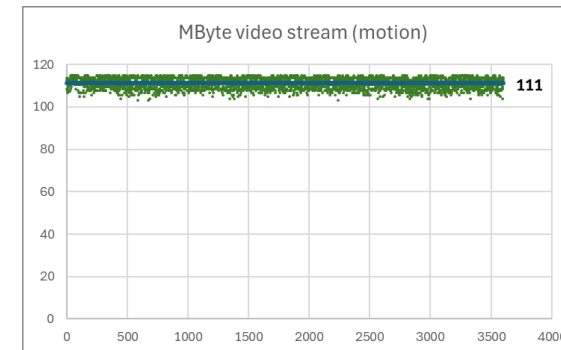
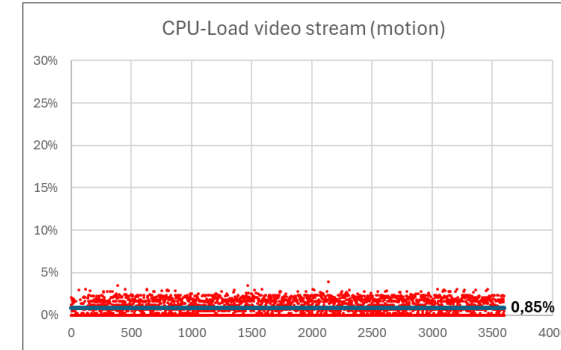
App 1: ecopower.py



App 2: ffmpeg



App 3: motion



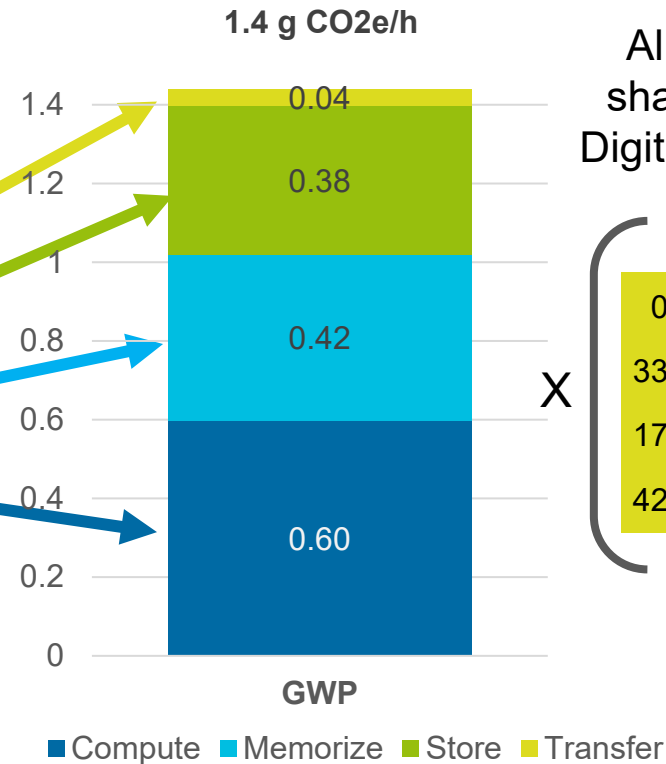
	ecopower.py	ffmpeg	motion	Sum
CPU-Load_average	4,92%	4,17%	0,85%	9,94%
RAM-used_average	24 MByte	28 MByte	111 MByte	163 MByte
SSD-used (assumption: 1/3 of total used)	2,1 GByte	2,1 GByte	2,1 GByte	6,4 GByte
Network-speed_average	2 kByte/s	0 kByte/s	48 kByte/s	50 kByte/s

Environmental impact of energy consumption (*usephase emissions*)

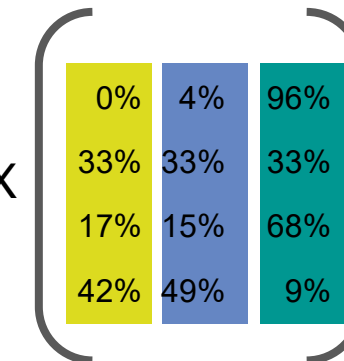
- $P_{\text{average}} = 3.42 \text{ W}$
- Software usage for 1 hour

E_{tr}	=	0,1Wh
E_{st}	=	0,9Wh
E_{me}	=	1Wh
E_{co}	=	1,42Wh
Summe	=	3,42Wh

- Allocation shown here using the example of Global Warming Potential (GWP) in the use phase

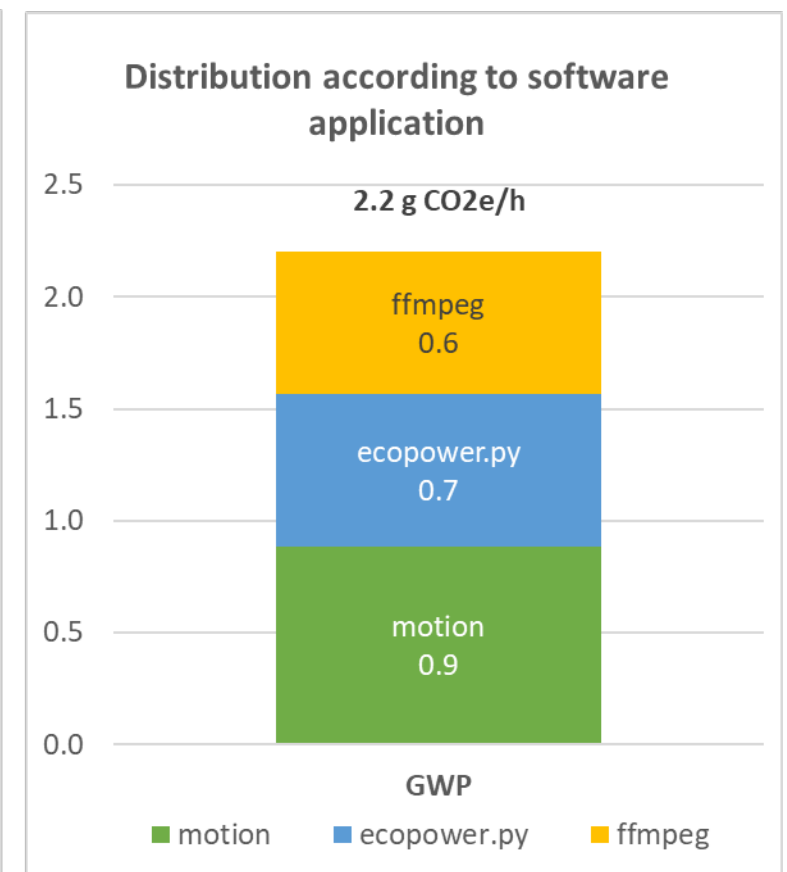
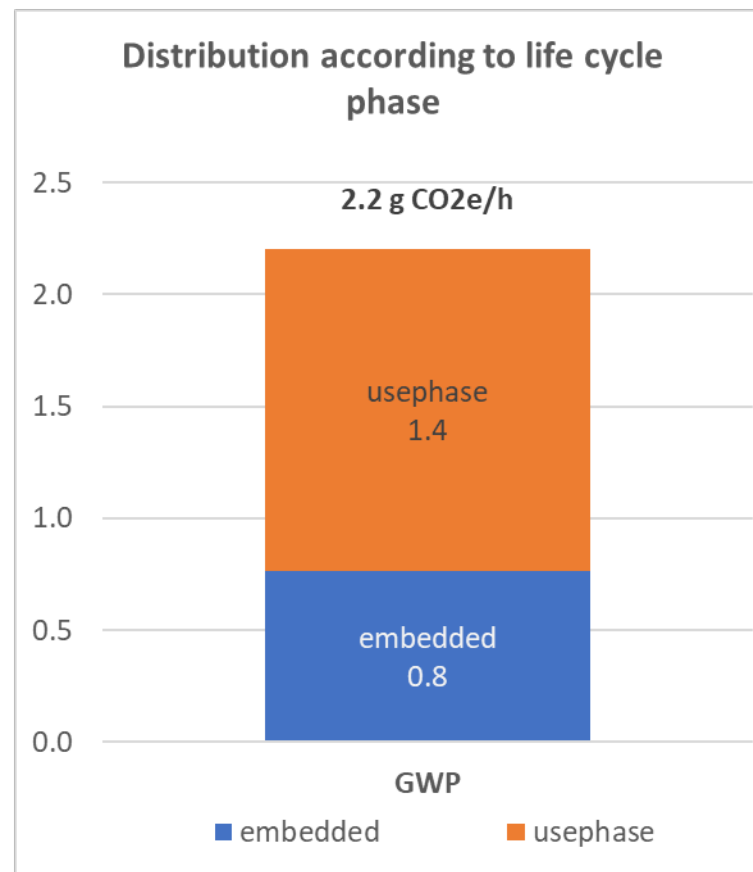
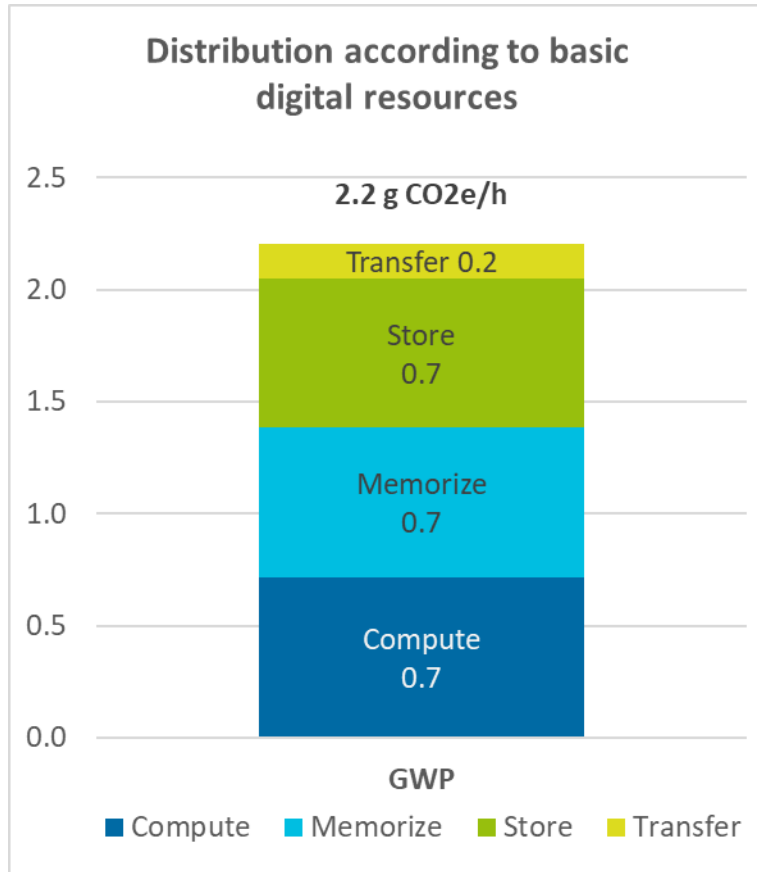


Allocation by shares of used Digital Resources



→ This allocation is applied in the same way to manufacturing effort.

Results: Running 3 Software Apps (*embedded* + *use phase emissions*)



Conclusions from using the LCA methodology

- The described (eco:digit) methodology can be used to determine the **environmental impact** of software, software bundles, and software running in **shared infrastructures**.
 - It works with **any environmental impact category** (e.g. GWP, ADP, Water, WEEE, TOX)
 - It helps identify **where** the **major environmental impacts** lie (e.g. manufacturing of hardware, energy demand in use phase, choice of physical components).
 - It also highlights the **key issues** to be optimised through green coding (e.g. CPU or RAM usage, data transfer, idle consumption).
 - It provides a direct response to any change of code or hardware to **environ. improvements**.
 - It includes the **utilisation** and **lifetime of hardware** in the assessment and allows also their optimization.
- The method should not only be used in a scientific context
- Standardisation could be used to make it available to a wider target group

On the way to standardization (1): Overview of existing initiatives for determining the environmental impact of software

Metrics initiatives

- <https://github.com> ...
 - /Breakend/experiment-impact-tracker
 - /cloud-carbon-footprint/cloud-carbon-footprint
 - /fvaleye/tracarbon
 - /mlco2/codecarbon
 - /saintslab/carbontracker
 - /sb-ai-lab/Eco2AI
- <https://aws.amazon.com/de/sustainability/tools/aws-customer-carbon-footprint-tool/>
- <https://www.microsoft.com/en-us/sustainability/emissions-impact-dashboard>
- <https://cloud.google.com/carbon-footprint>

Standardisation initiatives

- ISO/IEC 21031 Information technology - Software Carbon Intensity (SCI) specification
- ISO/IEC CD TS 20125 Information technology - digital services ecodesign - ecopractices for life cycle stages
- ISO/IEC 5055 Information technology - Software measurement - Software quality measurement - Automated source code quality measures
- ISO/IEC 25010 Systems and software engineering - Systems and software Quality Requirements and Evaluation (SQuaRE) - Product quality model
- ISO/IEC/IEEE 12207 Systems and software engineering - Software life cycle processes
- ISO/IEC CD TR 20226 Information technology - Artificial intelligence - Environmental sustainability aspects of AI systems
- ISO/IEC 5338 Information technology - Artificial intelligence - AI system life cycle processes
- ISO/IEC DIS 12792 Transparency taxonomy of AI systems
- CEN-CENELEC Preliminary Work Item (PWI) Sustainable Artificial Intelligence - Guidelines and metrics for the environmental impact of artificial intelligence systems and services

→ There are a variety of measuring and standardisation initiatives for software

- However, their focus is often limited (e.g. only energy consumption in the use phase) and they cover only a few environmental impacts (e.g. greenhouse gas emissions)

On the way to standardization (2): Necessity for standardisation of a life cycle assessment method for software

- Expectations for a standardised method:*
- Standards for resource-efficient software may **define testing and measurement methods** to assess various aspects of software and software development processes, including their energy efficiency.
- Standards can help companies to **clarify and differentiate terms** in the realm of resource-efficient software (e.g. sustainable tech, green coding, green software, green ICT).
- Certification bodies can validate the adoption of resource-efficient software practices by providing **recognized certifications** that demonstrate compliance with standards.
- Standards may **prevent greenwashing** and build trust regarding sustainability claims made by companies. This may concern consumers as well as companies in the choice of a product or service providers.
- **Transparency**: Allowing users and consumers to have a **clear indication** of the energy consumption of the respective software or digital services.

* Source (shortened list): ISO Open Consultation: Resource-efficient software (Oct 24 – Jul 25)

<https://www.din.de/de/forschung-und-innovation/themen/klimawandel/ressourceneffiziente-software-im-fokus-der-iso-open-consultation>

On the way to standardization (3): Our current standardisation activities

- DIN Deutsches Institut für Normung e. V.
 - Normenausschuss Informationstechnik und Anwendungen (NA 043)
 - Fachbereich Grundnormen der Informationstechnik (NA 043-01 FB)
 - Arbeitsausschuss Ressourceneffiziente Software und Künstliche Intelligenz (NA 043-01-08 AA)
 - **DIN-Arbeitsgruppe: Bilanzierung des Ressourcenbedarfs von Software, KI-Anwendungen und digitalen Dienstleistungen**
 - **(DIN working group: ≈ „Assessing the resource requirements of software, AI applications and digital services”)**
- The working group is preparing the basics for an ISO standard that describes how the environmental impact of software can be determined.
- It is based on existing **life cycle assessment standards** and also specifies
 - how the **scope** of the assessment must be described,
 - which **life cycle phases** must be taken into account,
 - which **allocation rules** can be applied,
 - and how the **quality** of the assessment results can be ensured.

Thank you very much for your attention!

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Methodology description: <https://ecodigit.de/en/home/publications>