

The Climate Needs FAIR & FOSS: A Sustainability Perspective on Research Data and Software Management



Hochschule 2035 – Jahrestagung der Gesellschaft für Informatik

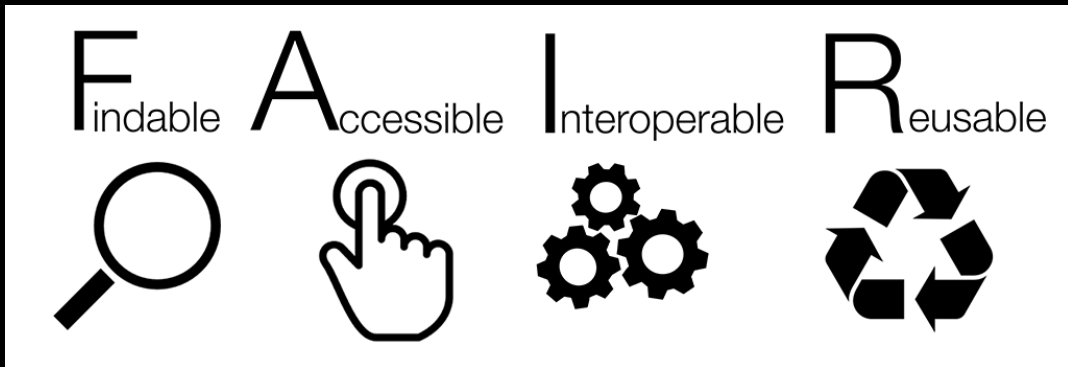


Slides available under "conferences/talks/":

<https://invent.kde.org/teams/eco/opt-green/>



FAIR & FAIR4RS Data Management – (Re-)Use of Digital Objects



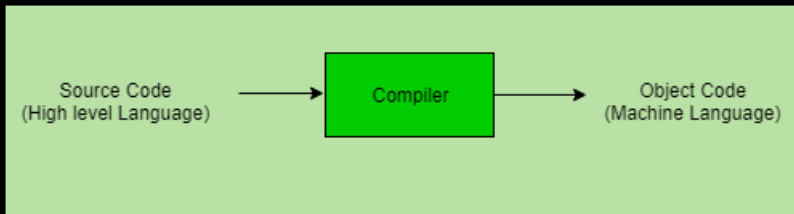
https://knowledgebase.nfdi4chem.de/knowledge_base/docs/fair/

FOSS Source Code – Legal Rights of Derivatives

```
int main(){  
    printf("Hello World!");  
    return 0;  
}
```

Richard E. Buckman & Joshua Gray, "A Note On Software" in *Free Software, Free Society*, p. 3

Binary Code



<https://media.geeksforgeeks.org/wp-content/uploads/20190823140215/compiler.png>

Example

```
1100011110111010100101001001001010101110
011010101001100000111100101101010111101
010011111111110010110110000000010100100
0100100001100101011011000110110001101111
0010000001010111011011110111001001101100
```

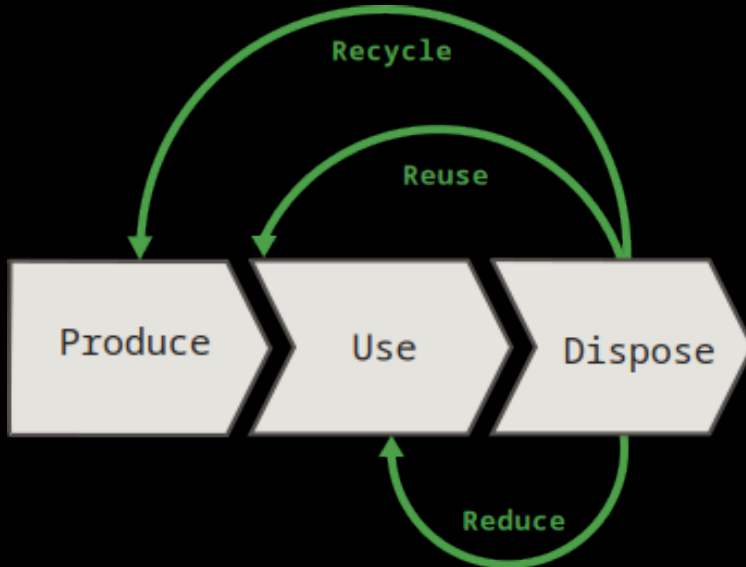
Richard E. Buckman & Joshua Gray, "A Note On Software" in *Free Software, Free Society*, p. 3

IT and Data Governance Strategies

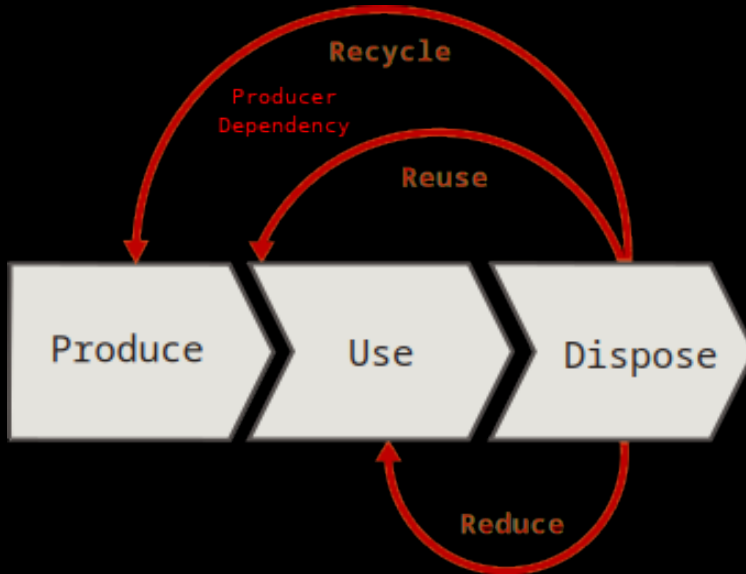
FAIR vs. **un-FAIR**
Data Management

Free vs. **Proprietary**
Software License

Linear vs. Circular Model



Producer Dependency – Inefficient Use of Energy and Resources



What's the Problem?



Image (modified) from Karanjot Singh published under a CC BY-SA 4.0 license:

<https://eco.kde.org/blog/2022-03-03-sok22-kde-eco/>

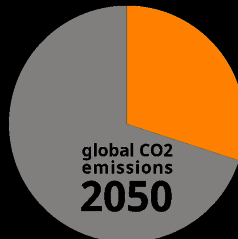
*“Computing can help mitigate climate change
but must **first cease contributing** to it.”*



2,5 %



1,8 % - 3,9 %



30 %

ACM Tech Brief (2021): <https://dl.acm.org/doi/pdf/10.1145/3483410>

See also Freitag et al. 2021: <https://www.sciencedirect.com/science/article/pii/S2666389921001884>

Manufacturing Alone is Half of Total in ICT (2019)

WORLDWIDE ICT ELECTRICITY CONSUMPTION 8 TO 9% OF TOTAL

FIGURES FROM 2019 ~8.5%

WORLDWIDE ELECTRICITY CONSUMPTION ~23500 TWH

DATA CENTRES	~ 200	TWH
NETWORKS: INTERNET & RAN	~ 250	TWH
END USERS	~ 550	TWH
MANUFACTURING OF ICT	~ 1000	TWH
ICT ELECTRICITY CONSUMPTION	~ 2000	TWH

Table 1. Summary of the International Energy Agency's (IEA) estimates for the year 2019 of the electricity consumption (in terawatt-hours) worldwide by different sectors of ICT, namely data centers, networks including the radio access network and end users, and the manufacturing of ICT equipment, which represents roughly 50% of the total amount.

"Electricity Consumption by ICT: Facts, trends, and measurements" (2023, ACM): <https://dl.acm.org/doi/pdf/10.1145/3613207>

Disproportionate Impact of Device Production

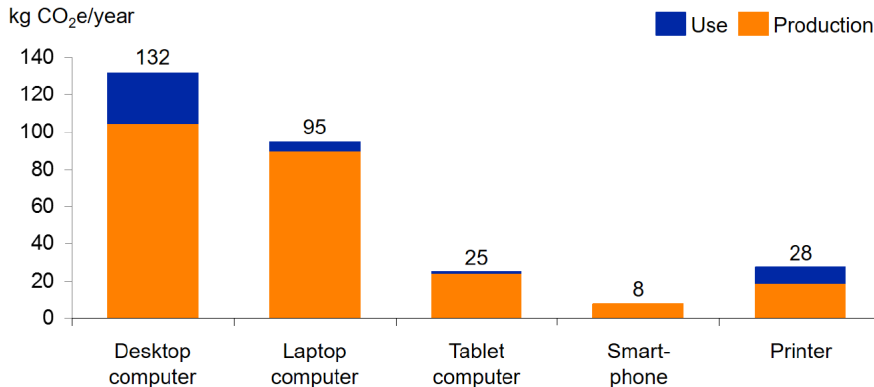


Figure 2: Average annual greenhouse gas emissions per end-user device during production and use by device type. The annual values of production emissions (grey) are based on current average useful lives of the devices.

From (modified): "Opportunities and Risks of Digitalization for Climate Protection in Switzerland" (2017):
https://www.zora.uzh.ch/id/eprint/141128/10/Study_Digitalization_Climate_Protection_Summary_Oct2017.pdf

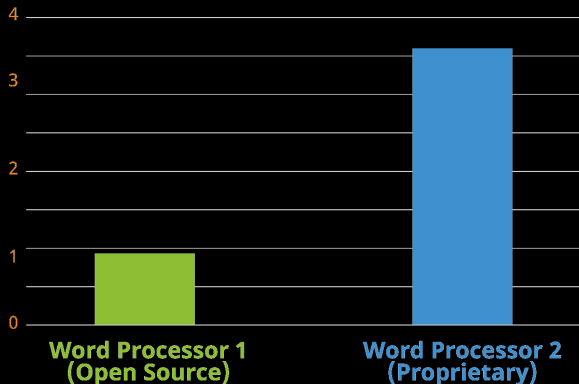
Production impacts “are so high” that even with a “10% increase in the energy efficiency [. . .], replacement of the older notebook can only be justified

after 33 to 89 years”

German Environmental Agency Report

Energy Consumption Depends On Software ... And Data Formats

Watt-hours

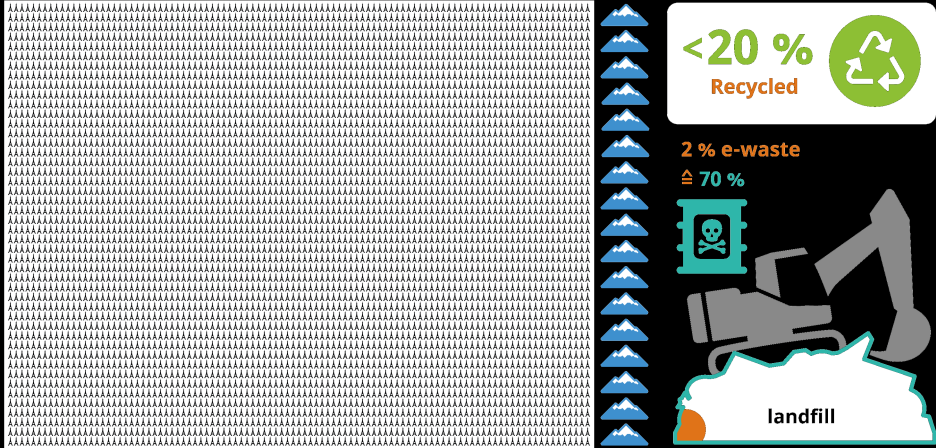


Adapted from: <https://www.umweltbundesamt.de/publikationen/entwicklung-anwendung-von-bewertungsgrundlagen-fuer>

Dispose

“Tsunami of E-Waste” – Achim Steiner, UNEP

E-waste 2016 = 4500 Eiffel Towers = Height of 170 Mount Everests



Based on report: <https://www.itu.int/en/ITU-D/Climate-Change/Documents/GEM%202017/Global-E-waste%20Monitor%202017%20.pdf>

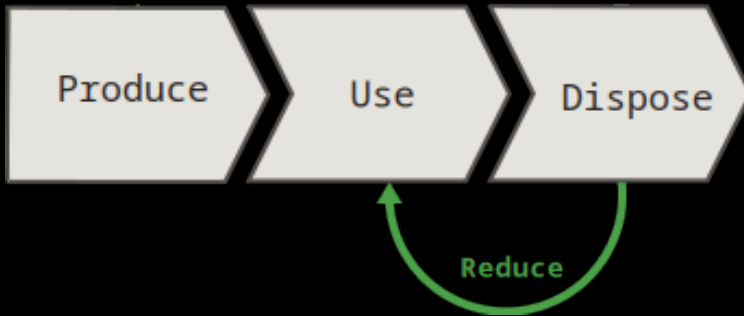


Image by Muntaka Chasant: https://en.wikipedia.org/wiki/File:Agbogbloshie,_Ghana_-_September_2019.jpg

FAIR & FOSS

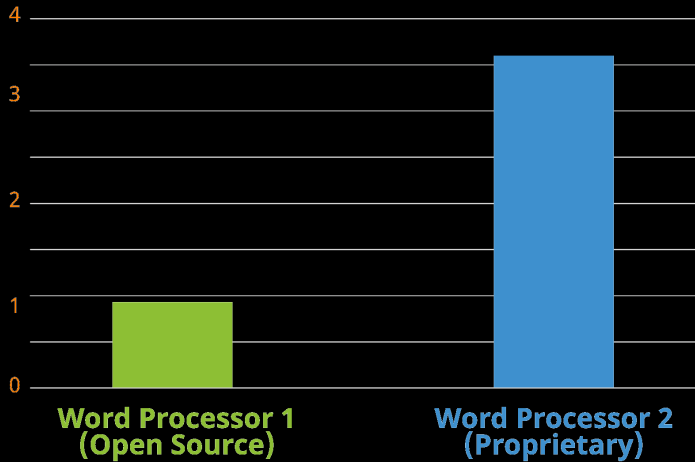
Reduce, Reuse, Recycle

FAIR & FOSS – To Reduce Energy and Resource Consumption



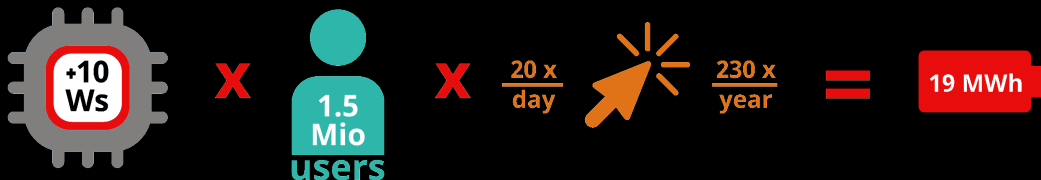
FAIR Can Stop Vendor Lock-In & Lower Hardware Demands

Watt-hours



Plot adapted from: <https://www.umweltbundesamt.de/publikationen/entwicklung-anwendung-von-bewertungsgrundlagen-fuer>

Energy Inefficiencies Scale Up



Adapted from Detlef Thoms HPI course: <https://open.hpi.de/courses/cleanit2021/items/5DHsS3tJsXAqfUE4q4F82Z>

FOSS Combats Hardware Obsolescence Driven by Software



Windows 10 support ending means more e-waste

240 million PCs ineligible for Windows 11 could become e-waste from October 2025



Incompatibility with Windows 11 prevents partners and ITAD firms from refurbishing and reselling still-viable PCs



Donating unsupported devices to disadvantaged communities globally presents challenges for digital equity



Microsoft will offer Extended Security Updates for Windows 10 from 2025 until 2028, but at an undisclosed annual cost

If all the PCs ineligible for Windows 11 were folded laptops stacked one on top of another, they would be 4,080km tall – 600km taller than the moon!



Source: Canalys estimates, PC Service and Sustainable Ecosystems Analysis, December 2023



Windows Lab (left) (CC BY-ND 2.0): <https://www.flickr.com/photos/29701609@N08/3929444859>

Screenshot (right) from: <https://www.canalys.com/insights/end-of-windows-10-support-could-turn-240-million-pcs-into-e-waste>

System Requirements – Independence with FAIR & FOSS



cedrus.

SuperLab > Download

SuperLab 6

SuperLab 6 for Windows

SuperLab 6 for Mac

tobii

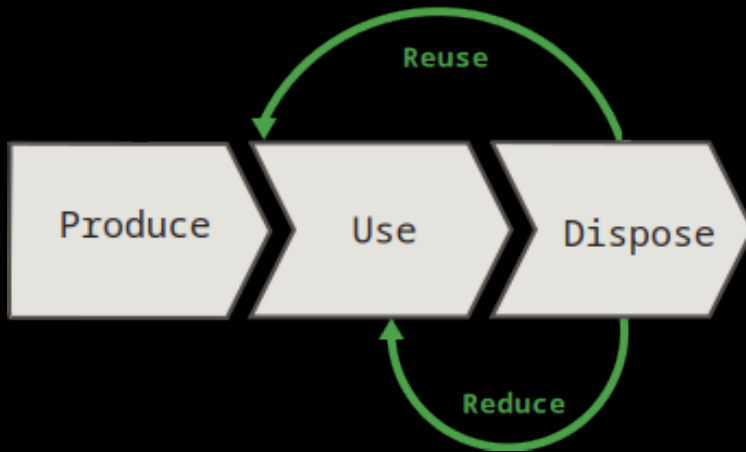
Open-source research toolbox support

- Full integration with [PyGaze](#) (Python), enabling easier use of Tobii eye trackers
- Comprehensive code example, guiding the use of Tobii Pro SDK with [Psychtoolbox \(Matlab\)](#)

Screenshot (left, modified) from: <https://www.cedrus.com/superlab/download.htm>

Screenshot (right, modified) from: <https://www.tobii.com/products/software/applications-and-developer-kits/tobii-pro-sdk>

FAIR & FOSS – To Reuse Research Data and Software



Reusing Software – Not Wasting Energy Reinventing the Wheel

[illegible]

https://cran.r-project.org/web/packages/available_packages_by_date.html

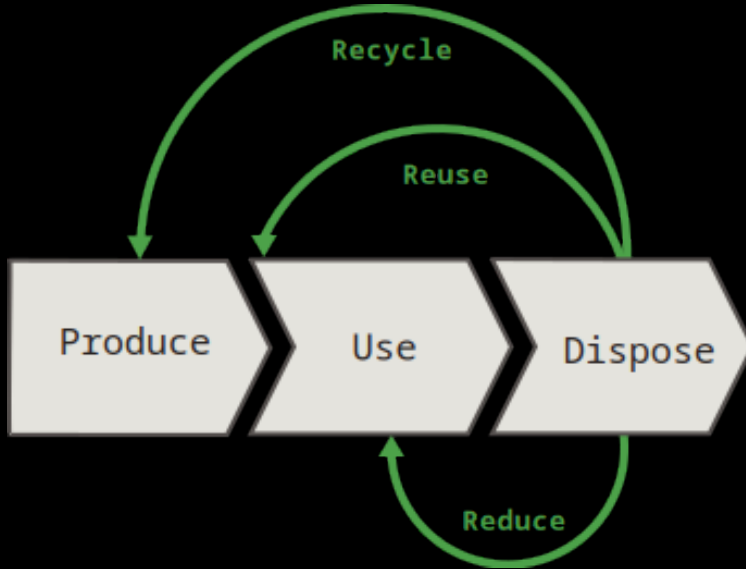
Embodied Carbon of Software – For Example, CI/CD Pipeline

Total Estimated Carbon Cost of Testing Workflow for a Month

Repository	Estimated gCO2e consumed	Miles Driven by Car	Smartphones Charged to Full	Gallons of Gasoline Consumed
curl	6,824.27	17.5	830	0.768
django	337.78	0.866	41.1	0.038
flask	56.26	0.144	6.8	0.006
openmw	2,948.28	7.6	359	0.332

<https://www.green-coding.io/case-studies/carbon-cost-of-testing-pipelines/>

FAIR & FOSS – To Recycle Research Data and Software



Embodied Carbon of Digital Objects – Recycling for New Studies



CommunitiesMy dashboard

Log inSign up

Featured communities



EU Open Research Repository

Open repository for EU-funded research outputs from Horizon Europe, Euratom, and earlier Framework Programmes.

[Browse](#)

Recent uploads

September 11, 2025 (v1)

Presentation

Open

Qingbai ewer with carved peony scrolls. China, Song dynasty (960–1279), probably Northern Song; Jingdezhen kilns.
NONA, Dronova

Uploaded on September 11, 2025

Part of Global Archive of Antique Porcelain Authentication

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September 11, 2025 (2025-09-11)

Dataset

Open

7-Tage-Inzidenz der COVID-19-Fälle in Deutschland
Robert Koch-Institut

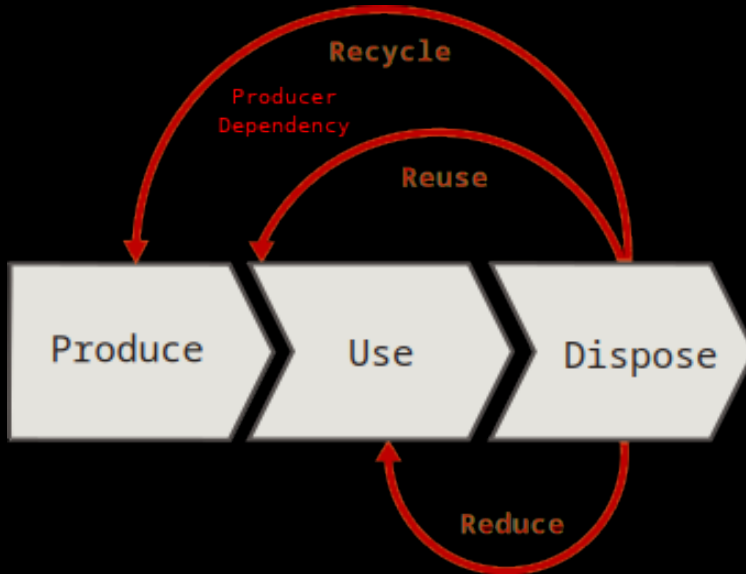
Im Datensatz "7-Tage-Inzidenz der COVID-19-Fälle in Deutschland" des Robert Koch-Instituts werden die täglich aktualisierten COVID-19-Inzidenzen auf Bundes-, Landes- und Landkreisebene basierend auf den Meldungen nach dem Infektionsschutzgesetz (IfSG) bereitgestellt. Die 7-Tage-Inzidenz wird definiert als Anzahl gemeldeter Fälle der letzten...

Why use Zenodo?

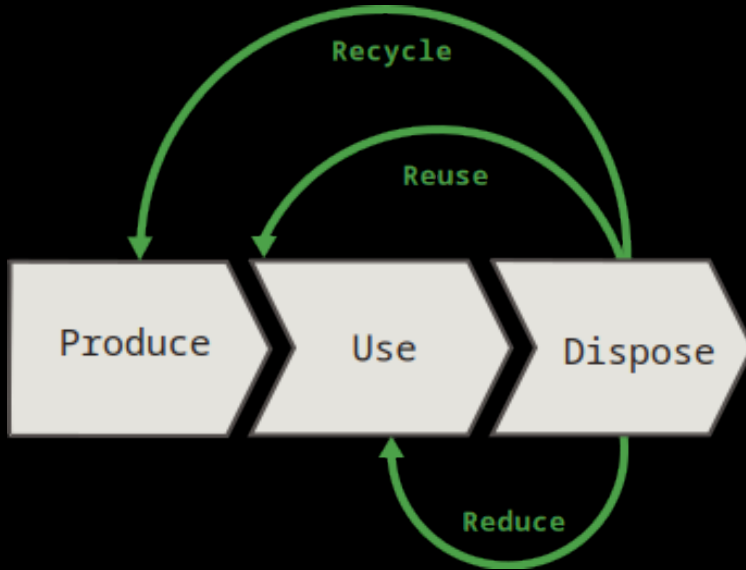
- **Safe** — Your research is stored safely for the future in CERN's Data Centre for as long as CERN exists
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- **Citeable** — Every upload is assigned a Digital Object Identifier (DOI), to make them citable and trackable
- **No waiting time** — Uploads are made available online as soon as you hit publish, and your DOI is registered within seconds
- **Open or closed** — Share e.g. anonymized clinical trial data with only medical professionals via our restricted access mode
- **Versioning** — Easily update your dataset with our versioning feature
- **GitHub integration** — Easily preserve your GitHub repository in Zenodo
- **Usage statistics** — All uploads display standards compliant usage statistics

<https://zenodo.org/>

Producer Dependency



FAIR & FOSS Interrupt the Linear Model



Rethink – To Reduce Energy and Resource Consumption

- Use **open data formats** for future interoperability
- Run **CI/CD pipeline** only when necessary
- Judiciously use **high energy-consuming tools** like genAI
- **Curate** archived data and software

Eco-Certified Software – Green Public Procurement

Institutional Policies For Sustainability

Blauer Engel recognizes **autonomy** and **transparency** as being crucial to sustainable software design!



ABC of Certification Criteria



Resource &
Energy Efficiency



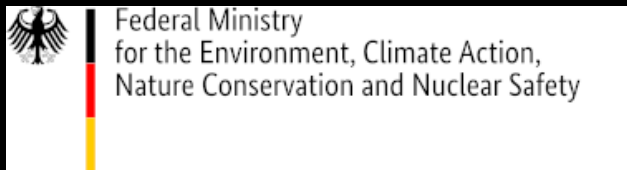
Potential
Hardware
Operating Life



User
Autonomy

Funding Notice

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