20e édition

infoprodigital

Forum TERATEC 25

21 & 22 MAI 2025 | Parc Floral, Paris

LE RDV des experts du supercomputing

HPC – IA – Simulation – Quantique

En partenariat avec

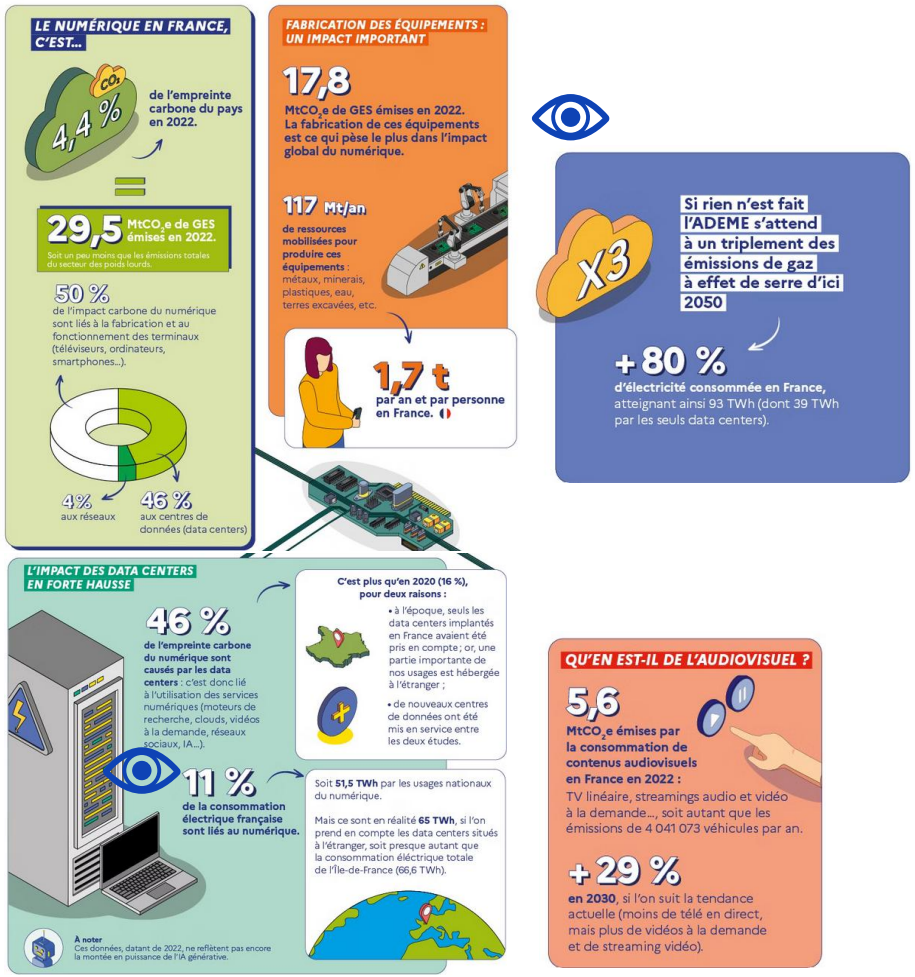
L'USINENOUVELLE L'USINEDIGITALE IT INDUSTRIE & TECHNOLOGIES Teratec

Forum TERATEC

Measuring the Carbon Footprint of Artificial Intelligence Algorithms: A practical approach

Dr. Gwenaëlle Berthier, Project Manager, IRT SystemX
Dr. Dimitra Politaki, Senior Research Engineer, IRT SystemX
Dr. Louis Verny, Senior Research Engineer – Theme Leader, TotalEnergies

Monitoring Carbon Footprint: A New Responsibility



https://infos.ademe.fr/magazine-janvier-2025/numerique-quel-impact-environnemental-en-2022/

- **EU Directive**: Carbon neutrality targeted by 2050.
- **Why it matters**: Monitoring carbon emissions is becoming essential.

Key Figures (Source: ADEME, ARCEP, French Senate Reports)

- **Digital sector (2022)**:
  - Accounts for **4,4%** of global greenhouse gas (CO_2) emissions.
  - Including **50%** from IT equipments
  - Including **46%** from datacenters
- **Projected Growth**:
  - Could rise by **x3 by 2050**.
- **Energy Use**:
  - **11%** of annual electricity consumption comes from digital services.
  - **61%** of that is from the **manufacturing phase**.
  - Only **39%** relates to the **usage phase**.

Forum TERATEC

Monitoring Carbon Footprint: A New Responsibility

https://alliancegreenit.org/qui-sommes-nous

https://boavizta.org/methodologie

https://ecoinfo.cnrs.fr/2020/05/06/ecodiag/

https://github.com/hubblo-org/scaphandre

https://greenspector.com/fr/solutions/conseil-numerique-responsable/

https://arxiv.org/abs/1910.09700

https://planet-techcare.green/

https://github.com/alumet-dev/alumet

And many others…. But,

Forum TERATEC

Challenges

Several **non-standardized and siloed approaches** exist, but no widely accepted reference methodology is currently available

Data reliability is limited: hardware manufacturers do not provide precise carbon impact

Lack of visibility into applications deployed in the cloud

Environmental Impact of Digital Technologies Project - in a nutshell (2024-2026)

Why?

Provide **tools for assessing digital environmental performance:** a methodology based on Life Cycle Assessment (LCA) defining indicators, and transparent and homogeneous calculation methods that concretely quantify the benefits and associated environmental costs

➡ **4 applied case studies**

Objectives - Developing tools to evaluate the environmental performance of digital technologies

- Define **evaluation rules on the environmental impacts** of physical components at every stage of the lifecycle of digital systems;
- Establish a **decision-making tool**
- Share with the scientific community **a systemic diagnostics guide on environmental impacts**

With?

Institutional Partner

Industrial partners

Academic Partners : CentraleSupélec • Laboratoire Interdisciplinaire des Sciences du Numérique (LISN) • Sorbonne Université

IEN Project (2024-2026) - Actions

Provide digital environmental performance assessment tools:
a methodology based on LCA and the definition of indicators, and transparent and homogeneous calculation methods which concretely quantify the gains and associated environmental costs

✓ 2 theses started in October 2024

Thesis #1 – Development of a methodology for assessing the environmental impacts of digital systems

CentraleSupélec
Laboratoire Interdisciplinaire des Sciences du Numérique (LISN)

Thesis #2 – Assessing the environmental footprint of DNS (Domain Name System)

Sorbonne Université

Sustainable Cyberarchitecture

Sustainable IT park

Sustainable AI

TotalEnergies' Challenges

Objectives

Estimating the **environmental costs of** AI process

Calculating Carbon Footprint

- Evaluate models and make recommendations
- Provide benchmarking models
- Provide KPI

Challenges

Estimating the costs associated with training and testing

- Complexity of AI Models
- Varying dynamic Workloads
- Data Variability
- Decision support
- Scalability Issues
- May be restricted by
- Hardware Architecture
- Dataset availability
- Energy consumption

Choosing the right hardware architecture

- Architecture type
- Optimization

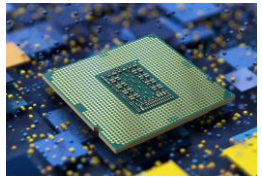
Expected outputs

Generic method to be applied to new emerging AI models

Innovative Platform for environmental cost calculation

Why a new SystemX platform?

CarbonTracker [1]	PyJoules [4]	Green Algorithms [2]	Experiment Impact Tracker [3]	SystemX platform
• AI-powered carbon emissions tracker • Estimate Environmental Impact • Sustainable Practices • Decision Makers Design & Implementation (++) • Python tool • Usable • Extensible • Flexible • Performance • Interpretable	Python library: monitors the energy consumed by specific devices of the host machine (++) PowerAPI toolkit (- -) it does not directly supply a CO2 equivalent value.	• Online tool. • Calculates the energy consumption and carbon footprint (++) user-supplied information in a web interface: • Runtime • Number of cores • Memory requested • Type of platform used • Type of cores • Location	• Measuring • reporting the impact of their machine learning experiments. (++) Python package	• Python • Extensible • Scalable • Modularity • Flexible • Transparency • Models executions • Many GHG metrics • User friendly



Source: https://www.pcworld.com/article/541489/how-to-check-cpu-and-memory-usage.html

Source: https://www.nvidia.com/en-us/geforce/graphics-cards/50-series/

Source: https://www.hp.com/us-en/shop/tech-takes/what-is-dram-dynamic-random-access-memory

IEN Project – One possible outlook/perspective

How Can We Accurately Measure the Carbon Impact of IT and AI?

May have an increase consumption with uses

Sustainable IT park

Open Source Experience (Dec.24)
https://youtu.be/0d93QYGKLlw?si=ecxaTcKJbmlihAMS

teclib'
Open IT Solutions

Hardware impacts?

Machine Learning extension?

Sustainable AI

TotalEnergies

Next Steps

- ✓ 1 publication done **State of the Art**
  - ✓ Ecosystem
  - ✓ Standards –Norms
  - ✓ Various measurements – KPIs
  - ✓ Existing Databases
  - ❑ **To be continuing: Measuring Energy Consumption**
  - ❑ **Especially, in a Machine Learning context**

- ❑ Conferences to be submitted in 2025

- ❑ Peer-reviewed scientific articles to be submitted in 2025

https://www.irt-systemx.fr/en/white-paper-environmental-impact-of-digital-technologies/

Forum TERATEC

Bibliography

CarbonTracker [1] | PyJoules [4] | Green Algorithms [2] | Experiment Impact Tracker [3]

[1] L. Anthony, B. Kanding, and R. Selvan, “Carbontracker: tracking and predicting the carbon footprint of training deep learning models,” Jul. 2020.

[2] L. Lannelongue, J. Grealey, and M. Inouye, “Green algorithms: quantifying the carbon emissions of computation,” CoRR, vol. abs/2007.07610, 2020. arXiv: 2007.07610. [Online]. Available: https://arxiv.org/abs/2007.07610.

[3] P. Henderson, J. Hu, J. Romoff, E. Brunskill, D. Jurafsky, and J. Pineau, “Towards the systematic reporting of the energy and carbon footprints of machine learning,” Journal of Machine Learning Research, vol. 21, no. 248, pp. 1–43, 2020. [Online]. Available: http://jmlr.org/papers/v21/20-312.html.

[4] M. c. Belgaid, R. Rouvoy, and L. Seinturier, Pyjoules: Python library that measures python code snippets, Nov. 2019. [Online]. Available: https://github.com/powerapi-ng/pyJoules.

Forum TERATEC

Thanks for your attention

Contacts:

gwenaelle.berthier@irt-systemx.fr

dimitra.politaki@irt-systemx.fr

Forum TERATEC

Comparison of Energy Measurement Tools and Frameworks

Extra slide

See White Paper
https://www.irt-systemx.fr/en/white-paper-environmental-impact-of-digital-technologies/

Tool/ Framework	Energy Meas.	Status	Monitored Resources	Energy Precision	Output unit	Domain	Limitations
Powermeter	✓	-	Hardware Energy	Hardware	Watts	General	Requires hardware investment
os utilities	×	-	Hardware and OS Resources	×, but also SW/Process for other resources	-	General	No actual energy measurement
Software Profilers	×	-	Software resources	Software methods/-classes	-	General	No energy output, only profiling
PowerScope	✓	-	Program counter, processes	Process, procedure	Joules	General	Requires hardware investment
pTop	✓	-	CPU, Disk, Network	Process level	Watts	General	Limited energy metrics
PowerTop	✓	Active	Hardware resources	Application	Watts	General	Focused more on tuning, not logging
Energy Checker	✓	End of Life	Hardware + app counters	Application	-	General	Discontinued, limited support
JouleMeter	✓	Deprecated	Hardware resources	Process	Joules	General	No longer maintained, basic estimation
PowerAPI	✓	Active	HW resources, thread/container/VM	Container/process/threa	Watts	General	Setup complexity for distributed use
Jalen	✓	-	Software resources	Code blocks (Java)	Joules	Java	Java-specific
CodeCarbon	✓	Active	CPU, RAM, GPU	Code blocks (Python), HW	gCO_2eq	ML/DL	Focused on ML
Carbontracker	✓ + prediction	Active	CPU, GPU, DRAM	Code blocks (Python)	gCO_2eq	ML/DL	Focus on training only, estimates
Scaphandre	✓	Active	CPU, DRAM	HW/VM	Joules or Watts	General	Limited device support
Alumet	✓	Active	CPU, GPU, DRAM	Hardware	Joules	General	Newer project, still maturing
Energy Scope	✓	Abandoned	CPU, DRAM, GPU	Hardware	Joules	General	No longer maintained
PowerJoular	✓	Active	CPU, GPU	HW + process, VM	Joules	General	Needs kernel support
pyJoules	✓	Active	CPU, RAM, GPU	Hardware	Joules	ML/DL	Limited to Linux, Python
Experiment Impact Tracker	✓	Unsupported	CPU, RAM, GPU	Hardware	gCO_2eq	ML/DL	No longer maintained, outdated dependencies
Boavizta API	×	Active	CPU, GPU, storage, network	Estimation model	gCO_2eq	General	No real-time data, estimate-based
Green Algorithms	×	Active	HPC specs	Spec-based formula	gCO_2eq	HPC/ML	Offline estimation only, requires specs
Ecologits TEMME	✓	Active	CPU, GPU, Memory, Disk I/O, Network Interfaces	Hardware	millijoules (mJ), joules (J)	HPC, ML/LLM	Hardware Dependency, Overhead, Platform Support

TABLE 2: Comparison of energy measurement tools and frameworks