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Measuring what matters: Closing the gaps in assessing AI's environmental impact

2026 Report

Green Digital Action

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ISBN

978-92-61-42181-6 (PDF version)

978-92-61-42191-5 (Electronic version)

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Foreword by the Secretary-General of the International Telecommunication Union (ITU)

As digital transformation accelerates at an extraordinary pace, so does the urgency of addressing the multiple environmental crises confronting humanity.

While digital technologies – including artificial intelligence (AI) – offer enormous potential in addressing these crises in areas like optimized energy systems and more accurate climate modelling, the rapid scaling of AI across borders also increasingly strains electricity grids, water resources, and raw material supply chains.

This interdependent, global nature of digital and environmental challenges points to international collaboration as the only way to manage and eventually overcome them.

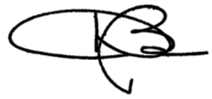
Collaboration, in turn, depends on shared, accurate and reliable data. But as the saying goes: we cannot manage what we do not measure. This report, *Closing the Gaps in Assessing AI's Environmental Impact*, offers a blueprint for moving from fragmented estimates to empirical accountability, as part of ITU's *Measuring What Matters* series.

While a previous report identified the challenges of data opacity, this follow-up publication offers a technical and policy framework to address them. Drawing on the results of global hackathons led by ITU, it maps actionable tools – from real-time telemetry to standardized sustainability dashboards – that can unlock the data needed for responsible and sustainable AI development in practice, not just in principle.

Through initiatives like Green Digital Action, ITU is working to ensure that technological progress does not come at the expense of the ecosystems and resources on which humanity depends. This means, for example, examining issues such as a circular economy for AI hardware and embedding environmental accountability into standard workflows and procurement processes. This report calls on governments, industry leaders, academia and civil society to unite under a transparent and accountable framework for measuring AI's environmental impact.

By closing the measurement gaps identified in this report, we lay the groundwork for AI development that is accountable, resource-conscious, and aligned with our shared values.

Together with our members and partners, ITU is proud to lead this work – bridging digital and environmental gaps through the standards, bold partnerships, and evidence-based frameworks that the urgency of this moment demands. I hope you'll join us.



Doreen Bogdan-Martin
Secretary-General, International Telecommunication Union

Foreword by the Director of the ITU Telecommunication Standardization Bureau

As artificial intelligence (AI) transforms industries, economies, and societies, its rapid growth brings significant environmental implications. Energy consumption, water usage, and greenhouse gas emissions associated with AI are rising sharply. Tech innovation must support, not hinder, climate action. To achieve this, the global tech industry needs to better understand and manage its positive and negative impacts.

The findings of our report, "*Measuring what matters: How to assess AI's environmental impact*," shows that the potential for greening digital remains obscured by inconsistent measurement practices and fragmented accountability.

Global solutions are the focus of this follow-up report. It synthesizes the innovative outcomes of the AI environmental footprint measurement hackathon with the aim of moving closer to common, transparent measurement criteria and reporting frameworks and associated international standards.

Current gaps–including a reliance on indirect estimates and a lack of data on Scope 3 emissions and water consumption–limit informed decision-making. To close these gaps, this report proposes practical solutions such as real-time telemetry tools and standardized metrics across the full AI lifecycle–from hardware manufacturing and training to inference and end-of-life management.

The International Telecommunication Union (ITU) is committed to uniting developers, governments, and civil society through its standardization work and initiatives like Green Digital Action. By integrating sustainability scoring into government and industry decisions and fostering a circular economy for hardware, we can ensure that AI technologies advance in harmony with climate goals.

Seizo Onoe
Director of the ITU Telecommunication Standardization Bureau

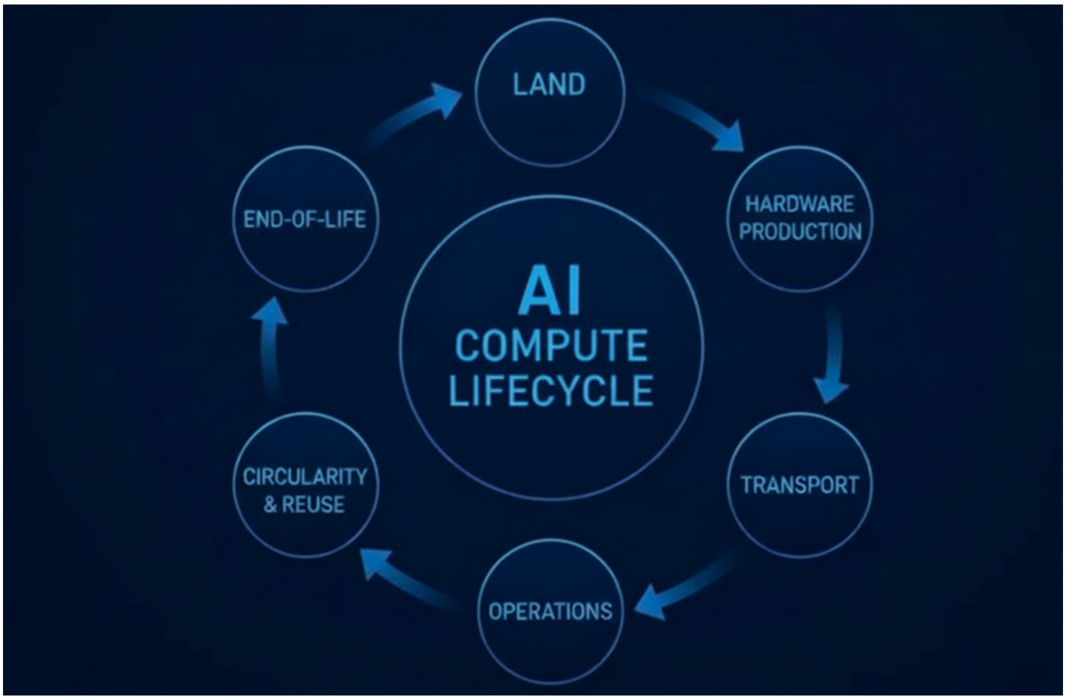
Executive Summary

As artificial intelligence (AI) technologies continue to expand rapidly across industries and society, concerns about their environmental footprint are intensifying. While the potential benefits of AI for economic growth, innovation, and climate solutions are significant, there remain crucial gaps in how AI's environmental impact – including energy consumption, water use, greenhouse gas emissions, and electronic waste – is measured and managed. The pioneering ITU report "*Measuring what matters: How to assess AI's environmental impact*" identified critical challenges such as reliance on indirect estimates, fragmented data across AI lifecycle stages, and a lack of standardized, transparent frameworks for reporting and accountability.

This report summarizes the solutions from the AI environmental footprint measurement hackathon and proposes practical solutions and policy recommendations to accelerate sustainable AI development. Key recommendations include the development and adoption of real-time telemetry tools for empirical measurement across the full AI lifecycle—from hardware manufacturing through training, inference, and end-of-life management. It calls for international collaboration to establish standardized metrics, reporting frameworks, and open data sharing, enabling cross-sector transparency and comparability.

The report emphasizes closing data gaps on underreported metrics such as water consumption, Scope 3 supply chain emissions, and infrastructure impacts, alongside efforts to empower consumers and stakeholders through accessible environmental impact dashboards and labels. Policymakers are urged to integrate sustainability scoring into regulatory and procurement decisions while fostering circular economy incentives for AI hardware.

Figure 1: AI compute resources life cycle /stages



Ultimately, the report calls for a multi-stakeholder approach uniting developers, industry, governments, civil society, and research organizations toward harmonized standards and ongoing innovation in AI environmental accountability. By embedding these solutions into practice, the global community can ensure that AI technologies advance in harmony with climate goals and responsible resource stewardship, unlocking AI's promise as a tool for good without compromising planetary health.

Acronyms and abbreviations

AI	Artificial Intelligence
CO_2	Carbon-dioxide
CO_2e	Carbon-dioxide-equivalent (Carbon footprint)
ESG	Environmental, Social, and Governance
GPU	Graphics Processing Unit
IoT	Internet of Things
ITU	International Telecommunication Union
ISO	International Organization for Standardization
KPIs	Key Performance Indicators
kWh	Kilowatt-hour (Energy consumption)
PUE	Power usage effectiveness
TDP	Thermal Design Power
WUE	Water usage effectiveness

Measurement and transparency for AI sustainability

Robust measurement and transparency are critical for AI sustainability because they provide an empirical foundation to understand, manage, and reduce the environmental impacts of AI technologies. Without accurate, granular on resource consumption such as energy, water, and carbon emissions across AI's full lifecycle—from hardware manufacturing to training, inference, and disposal—stakeholders cannot effectively identify hotspots of inefficiency or environmental harm. This hamper informed decision-making for developers, policymakers, and users aiming to minimize AI's ecological footprint.

Transparency ensures accountability by making environmental performance data accessible and comparable across organizations and regions, which helps avoid greenwashing and promotes trust. It empowers consumers, regulators, and investors to support sustainable AI practices and drives industry-wide adoption of standards and best practices. Ultimately, robust measurement and transparency serve as essential preconditions for policy frameworks, innovation, and collaboration needed to align AI development with global climate goals and sustainable resource use, enabling AI to be a positive force without compromising planetary health.

Measurement challenges and gaps

- Overreliance on proxies and indirect estimates hinders accuracy and timeliness.
- Fragmented metrics exclude significant lifecycle phases, notably inference and supply-chain (Scope 3) emissions, training emissions and emissions inclusive of the full infrastructure stack required.
- Limited transparency and lack of standardized units impede comparability and trust.
- Underreporting of water footprint and e-waste obscures full environmental impact.
- User behaviour and operational context remain insufficiently connected to impact data.

Solutions addressing gaps in measurement and reporting

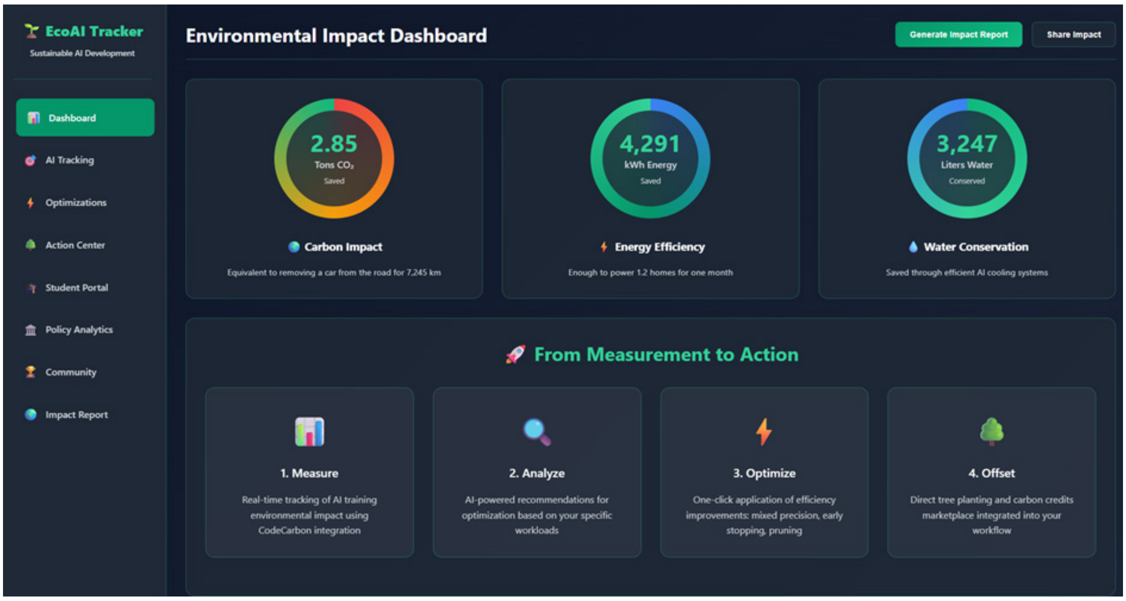
Building on the foundational insights of the original "Measuring What Matters" report, this report synthesizes recent innovations and practical implementations designed to address critical gaps in AI environmental footprint measurement. The report highlights a movement from proxy-based, fragmented assessments toward granular, lifecycle-inclusive, and standardized measurement frameworks empowered by multi-stakeholder collaboration. Embedding transparency, user empowerment, and scalability, these advances form the backbone for accountable and sustainable AI development aligned with global climate and resource stewardship goals.

Innovations in real-time measurement

AI Eco-Twin Calculator

An interactive tool estimating Graphics Processing Unit (GPU) energy, carbon, and water use for AI training with real-time feedback and scenario modelling. It combines hardware Thermal Design Power (TDP), Power Usage Effectiveness (PUE), and regional grid emissions to provide actionable footprint data for model developers.

Figure 2: EcoAI Tracker dashboard implementation example



GreenPulse Proof of Concept (PoC)

Modular Internet of Things (IoT) sensors capture live energy use and water flow in AI workloads, feeding real-time dashboards without reliance on external cloud computing. Designed for scalable deployment from small labs to large edge AI systems, it supports inclusivity and cost-effectiveness.

Environmental Footprint PoC

Simulates water usage in data centre cooling with physical sensors measuring flow and water quality, revealing water footprint visibility gaps and empowering local understanding of AI's hidden water demands.

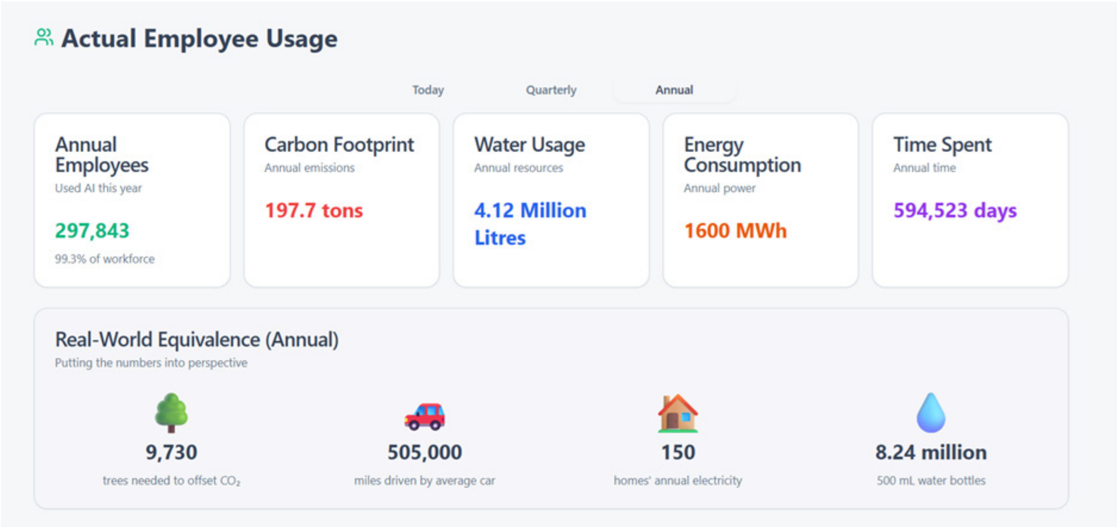
GreenMind User-Centric Model PoC

Real-time per-query environmental impact calculation is achieved by integrating telemetry data, incentivizing sustainable user behaviour through prompt optimization, gamification, and transparent emissions reports. Developed by Team GreenMind, the tool, SumEarth, serves as a critical bridge between opaque AI infrastructure and actionable environmental data.

SumEarth operates by capturing live telemetry from data centres and compute instances to provide a granular view of the carbon footprint associated with every individual AI interaction.

By surfacing these metrics directly to the user, the tool encourages "green prompting"—refining queries to be more computationally efficient.

Figure 3: Actual Employee Usage through SumEarth.AI implementation: https://sumearthai.lovable.app/



Addressing gaps in AI Lifecycle Analysis

Empirical, real-time lifecycle measurement

- interactive near-real-time estimations of GPU energy, Carbon-dioxide (CO_2) emissions, and water use during training.
- telemetry-based metrics to quantify inference-related emissions linked directly to user behaviour, promoting per-query transparency.
- modular IoT framework monitoring live energy and water consumption during AI workloads on small to large infrastructures, particularly suitable for resource-constrained environments.

International standardization and transparent protocols

- Introduction of "energy-size constant" metrics enabling standardized comparison across GPUs and models.
- A physics-based model benchmarks training energy across GPUs and AI models, facilitating standardized comparisons.
- Alignment with ISO and ITU lifecycle reporting standards ensures repeatability and international compliance.
- Open-source, documented software enables replicability and broad adoption.

Expansion of scope to underreported impacts

- Integration of Water Usage Effectiveness (WUE) metrics addressing critical global water stress risks.
- Exploration of Scope 3 lifecycle emissions including hardware manufacturing and e-waste as future reporting priorities.
- Emphasis on circular economy principles to reduce embedded resource use.

User and enterprise empowerment

- Deployment of visibility dashboards with real-time environmental KPIs embedded in AI tools.
- Behavioural nudges and climate-friendly prompt optimization foster responsible AI use at the individual and enterprise levels.
- Enterprise-level integration with ESG frameworks enables coordinated sustainability governance.

Scalability and inclusivity

- Modular architectures (IoT, lightweight calculators) democratize access for academia, developers, and emerging markets.
- Offline, low-cost solutions broaden participation across global contexts.

Proposed metrics and key performance indicators (KPIs) for reporting

This report suggests key metrics and KPIs for measuring and reporting AI's environmental impact. Below is an overview of the most common and critical metrics derived;

- Energy consumption (kWh) per lifecycle phase (e.g. training, inference) and per AI task.

- Carbon footprint (CO_2e) normalized to regional grids and model outputs.
- Water consumption (litres), WUE, water quality and stress indices.
- Hardware lifecycle impacts including e-waste volumes and Scope 3 emissions.
- PUE of infrastructure (especially data centres).
- Model size to energy consumption ratios (per-parameter and runtime energy efficiencies)
- Real-time per-prompt and per-inference footprint visibility (environmental cost estimations).

Figure 4: illustration of Metrics and KPIS

Core Metrics and KPIs for AI Environmental Impact

i. Energy Consumption (kWh)

   - Total energy used during AI training, inference, and hardware operation.
   - Metrics often broken down per model, per task, and per hardware component.
   - Include information regarding the energy mix used to complete the AI task, for example geographic location, date/time and energy type consumed.

ii. Carbon Footprint (CO_2e)

   - Greenhouse gas emissions associated with energy use, calculated based on on-site and regional power grid emission factors.
   - Often expressed as CO_2 equivalent emissions per model, per inference, or per unit of output.

iii. Water Usage (liters or cubic meters)

   - Water required for cooling data centres and infrastructure, especially relevant for water-intensive cooling systems.
   - WUE measures water use per unit energy consumed.

iv. Hardware and Supply Chain Impact

- Emissions and resource use linked to manufacturing, transportation, and end-of-life disposal.
- Critical for Scope 3 impact assessment.

v. Lifecycle Impact

- Total environmental footprint considering all phases: raw material extraction, manufacturing, operation, and decommissioning.
- Standardized via lifecycle assessment (LCA) frameworks.

vi. Resource Efficiency Metrics

- Model size relative to energy consumed (e.g., energy per parameter).
- Training time per unit of environmental impact.

vii. Water-Energy Nexus Metrics

- Ratio of water used to energy consumed, highlighting water stress implications.

viii. Operational KPIs

- PUE of data centres.
- Data centre environmental scores or ratings based on standardized metrics.

These KPIs, when collected consistently and transparently, form the backbone of effective measurement and reporting systems for AI sustainability. They address the gaps identified in the "*Measuring what matters: How to assess AI's environmental impact*" report by capturing the full lifecycle impacts and fostering accountability across the AI ecosystem.

Usage of metrics and KPIs

These metrics enable organizations to:

- Benchmark and compare environmental performance across models, data centres, and hardware.
- Set science-based targets aligned with global climate goals.
- Communicate environmental impacts effectively to stakeholders, regulators, and the public.
- Drive innovations toward more sustainable AI hardware, algorithms, and workflows.

Recommendations

Collectively, these recommendations chart a roadmap from fragmented, proxy-based estimates toward integrated, empirical, transparent, and actionable measurement frameworks—enabling accountability and progressive reduction of AI's environmental footprint globally.

- Scale deployment of empirical measurement tools integrated with AI infrastructure globally
- Formalize international, transparent, and harmonized standards for AI environmental reporting
- Include water, supply chain, and e-waste metrics alongside carbon in AI footprint frameworks
- Increase transparency via open data sharing, benchmarking, and accessible dashboards
- Empower users and enterprises through behaviour-aware tools and sustainability reporting integration
- Foster broad multi-stakeholder collaborations for continuous innovation and governance
- Prioritize inclusive solution development for resource-limited contexts
- Accelerate research and innovation in AI efficiency and sustainable hardware design

1. Develop and adopt real-time empirical measurement tools
    - Invest in telemetry systems, IoT sensors, and software dashboards to measure energy, water, and emissions throughout AI and hardware lifecycles, including training, inference, hardware manufacturing, and disposal.
    - Integrate with cloud providers and edge deployments for comprehensive coverage.
2. Standardize metrics and reporting protocols
    - Establish international standards and harmonized KPIs for AI environmental impact measurement, aligned with ISO and ITU lifecycle assessment guidelines.
    - Implement uniform units and transparent methodologies that enable comparable and verifiable disclosures.
3. Expand scope to underreported impact areas
    - Include water consumption, supply chain (Scope 3) emissions, and electronic waste in assessments and reporting.
    - Develop specific metrics like Water Usage Effectiveness (WUE) alongside existing energy and carbon KPIs.
4. Enhance transparency and data accessibility
    - Promote open disclosure of assumptions, proxy factors, and raw data.
    - Encourage shared databases and benchmarking platforms for independent verification and consumer access.
5. Empower users and organizations with behaviour-focused tools
    - Provide real-time feedback, gamification, sustainability scores, and prompt optimization tools to influence greener AI user behaviour.

    - Encourage enterprise adoption of sustainability dashboards and integration with ESG reporting.
    - Providing a 'lighter' default model, using approaches such as Model of Experts to route a prompt to the right 'expert' without activating all necessary params.

6. Foster multi-stakeholder collaboration

    - Establish networks involving AI developers, providers, policymakers, researchers, and civil society to co-create standards, pilot tools, and policy frameworks.
    - Support policy mechanisms that incentivize sustainability reporting and penalize greenwashing.

7. Focus on scalability and global inclusivity

    - Develop low-cost, modular solutions like IoT-based PoCs to democratize environmental monitoring in resource-constrained regions and smaller AI deployments.

8. Advance research and innovation in sustainable ai design

    - Investigate energy-efficient architectures, sustainable hardware design, and AI workload optimization techniques reducing carbon and water footprints.

Call to Action

- Embed sustainability across all AI development lifecycles.
- Global collaborative networks to harmonize metrics, pilot technologies, and scale adoption.
- Advance research to close knowledge gaps on water, supply chains, and hardware impacts.
- Mobilize policy frameworks incentivizing transparent environmental reporting and sustainable AI infrastructure.
- Promote education, capacity building, and inclusion to accelerate global action.
- Support users and enterprises with tools enabling immediate, actionable environmental insights.

Project Contributors

The Green Digital Action (GDA) initiative under the International Telecommunication Union (ITU) acknowledges the valuable contributions from the following organizations in preparing this publication:

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ISBN 978-92-61-42181-6

Published in Switzerland
Geneva, 2026