SLOVENSKI STANDARD
SIST-TP CEN/CLC/TR 18145:2025

01-april-2025

Okoljsko trajnostna umetna inteligenca

Environmentally sustainable Artificial Intelligence

Informationstechnik - Künstliche Intelligenz - Grüne und nachhaltige KI

Ta slovenski standard je istoveten z: CEN/CLC/TR 18145:2025

ICS:

13.020.20	Okoljska ekonomija. Trajnostnost	Environmental economics. Sustainability
35.020	Informacijska tehnika in tehnologija na splošno	Information technology (IT) in general

SIST-TP CEN/CLC/TR 18145:2025 en,fr,de

TECHNICAL REPORT

RAPPORT TECHNIQUE

TECHNISCHER REPORT

CEN/CLC/TR 18145

February 2025

ICS 13.020.20; 35.240.01

English version

Environmentally sustainable Artificial Intelligence

Informationstechnik - Künstliche Intelligenz - Grüne und nachhaltige KI

This Technical Report was approved by CEN on 10 February 2025. It has been drawn up by the Technical Committee CEN/CLC/JTC 21.

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Ref. No. CEN/CLC/TR 18145:2025 E

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European foreword

This document (CEN/CLC/TR 18145:2025) has been prepared by Technical Committee CEN/CLC/JTC 21 “Artificial Intelligence”, the secretariat of which is held by DS.

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1 Scope

This document provides a description of the main environmental sustainability issues that organisations or individuals that are developing and/or using Artificial Intelligence (AI) consider, in particular, in the context of the European energy systems and resources.

It is important to have a focus where AI helps in optimization and virtual deployment of engineering solutions [1], especially in Europe with limited natural resources. This document reviews the European AI landscape, with a context of environmental sustainability. This is addressed with a focus on European-specific aspects of AI demands for resources, as well as its potential to contribute to environmental sustainability in Europe [2]. The document creates an inventory of impacts and techniques to support environmentally sustainable use of AI, and an equitable access to computation resources.

Suggested improvements in AI resource management are focused on:

- reduction of the operational AI energy consumption (see section 5)
- reduction of other AI resource consumption (water, etc.) (see section 6)

The document also considers the potential benefits of using AI from a sustainability perspective. Methods of measuring the environmental sustainability impacts of AI are also quantified.

This document is intended to help with the development of new standards and complement existing European standards and standardization deliverables that define resource measurement for the use of AI. It describes best practices and indicates which techniques and management processes for improvement of AI resource performance and environmental viability. The document is expected to contribute to voluntary corporate social responsibility (CSR) in Europe, and increase sustainability awareness for individuals when designing, developing, and using AI. The aim is to create a focus on the responsible use of AI that prioritizes ethical considerations, human values, and an understanding of the social implications of AI design and use.

The document is aligned with equivalent activities in ISO/IEC/JTC 1/SC42/WG4, TR 20226 “Green and Sustainable AI”, but takes into account specific aspects of the European energy system that are not applicable elsewhere. In particular, sustainable energy supply provided via the European interconnectors will be taken into account when assessing AI carbon footprint. Additionally AI solutions for the optimization of energy use will be reviewed and quantified to balance the energy use of AI applications and services which make extensive use of energy. This report also identifies and addresses the United Nations Sustainable Development Goals [3, 4]. Additionally, this document aligns with ISO/IEC DIS 21031 Information Technology – Software Carbon Intensity (SCI) [5], ISO/DIS 59004 Circular Economy – Terminology, Principles and Guidance for Implementation, and the Greenhouse Gas Protocol (GHG), Product Life Cycle Accounting and Reporting Standard [6].

The upcoming EU AI Act in its current draft encourages voluntary assessment of companies for environmental sustainability.

2 Normative references

There are no normative references in this document.

3 Terms, definitions and abbreviated terms

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp/

— IEC Electropedia: available at https://www.electropedia.org/

3.1 Terms and definitions

3.1.1 Terms related to Artificial intelligence and Machine Learning

3.1.1.1
artificial intelligence
AI
<discipline> research and development of mechanisms and applications of AI systems

Note 1 to entry: Research and development can take place across a number of fields such as computer science, data science, humanities, mathematics and natural sciences.

[SOURCE: ISO/IEC 22989:2022]

3.1.1.2
artificial intelligence system
AI system
engineered system that generates outputs such as content, forecasts, recommendations or decisions for a given set of human-defined objectives

Note 1 to entry: The engineered system can use various techniques and approaches related artificial intelligence to develop a model to represent data, knowledge, process, etc which can be used to conduct tasks.

Note 2 to entry: AI systems are designed to operate with varying levels of automation.

[SOURCE: ISO/IEC 22989:2022]

3.1.1.3
dark data
information assets that organizations collect, process and store during regular business activities, but fail to use for purposes beyond those associated with the initial collection

3.1.1.4
internet of things
IoT
infrastructure of interconnected entities, people, systems, and information resources together with services which processes and reacts to information from the physical world and virtual world

[SOURCE: ISO/IEC 20924:2021]

3.1.1.5
machine learning
ML
process of optimizing model parameters through computational techniques, such that the model's behaviour reflects the data or experience

[SOURCE: ISO/IEC 22989:2022]

3.1.2 Terms related to environmental sustainability

3.1.2.1
environmental sustainability
state in which the ecosystem and its functions are maintained for the present and future generation

[SOURCE: ISO 17889-1:2021]

3.1.2.2
life cycle
evolution of a system, product, service, project or other human-made entity from conception through retirement

[SOURCE: ISO/IEC/IEEE 15288:2015: Systems and software engineering — Software life cycle processes

Note 1 to entry: ISO/IEC 24748-1:2018 Systems and software engineering — Life cycle management — Part 1: Guide for life cycle management and ISO/IEC/IEEE 15288:2015 Systems and software engineering — System life cycle processes provide unified and consolidated guidance of life cycle management of systems and software

3.1.2.3
life cycle assessment
LCA
systematic evaluation of the environmental impact of a product(s) that includes all stages of its life cycle

[SOURCE: ISO 17889-2:2023]

3.1.2.4
circular economy
economic system that uses a systemic approach to maintain a circular flow of resources, by recovering, retaining or adding to their value, while contributing to sustainable development

Note 1 to entry: The inflow of virgin resources is kept as low as possible, and the circular flow of resources is kept as closed as possible to minimize waste, losses and releases from the economic system. Resources can be considered concerning both stocks and flows

[SOURCE: ISO/DIS 59004]

3.2 Abbreviated terms

AI	Artificial Intelligence
CPU	Central Processing Unit
CSR	Corporate Social Responsibility
CNN	Convolutional Neural Network
DNN	Deep Neural Network

ENTSO-E	European Network of Transmission System Operators for Electricity
FFT	Fast Fourier Transform
FL	Federated Learning
GEMM	General Matrix Multiplication
GPU	Graphic Processing Unit
GWh	Giga-Watt hour
GUM	Guide to the Expression of Uncertainty in Measurement
HDC	Hyperdimensional Computing
HPC	High-Performance Computing
ICT	Information and Communication Technologies
IoT	Internet of Things
kWh	Kilowatt-hour
LCA	Life-Cycle Assessment
LLM	Large Language Model
ML	Machine Learning
NLP	Natural Language Processing
NN	Neural Network
PUE	Power Usage Effectiveness
PV	Photovoltaic
RAM	Random Access Memory
TSO	Transmission System Operator

4 Environmental impacts

4.1 General

The primary environmental impact of AI (and other computer software) is the use of electricity, which is produced in power stations using various fuels and a variety of power suppliers. Most of these resources used by AI are from fossil fuels, such as natural gas, oil and coal.

4.2 A definition of the issue

New technologies help improve lives of European citizens and bring major benefits to society and economy through better healthcare, more efficient public administration, safer transport, image analysis, optimization of use of resources, a more competitive industry and sustainable agriculture.

AI is developing rapidly and requires nonlinear growth of resources such as electricity and cooling systems consuming freshwater resources to stabilize the operational use and distributed use of resources to serve an increasing number of cloud service users.

However, some uses of AI lead to unprecedented energy and resource impact in its life cycles, i.e. training, deployment, and operational use.

In some European countries, such as France, majority of energy generation is nominated by nuclear fuel. In other European countries the fuel used is more complex. With the deployment of renewable energy sources, the complexity and intermittency of multiple types of generation are considered. The fuel mix used for energy generation in Europe is particularly complex. National Grid operators currently report fuel mix with a 30-min temporal resolution. The impact of cross-boundary European interconnectors, which deliver electricity from non-European countries with different fuel mixes, also needs to be considered. These complexities are analysed along with the associated uncertainties on fuel types to obtain a combined uncertainty of the operational indirect carbon emissions from the power supply used by AI. ISO/IEC Guide 98-3 – Uncertainty of Measurement – Part 3 Guide to the expression of uncertainty in measurement [7, 8] establishes the principles and rules which are used for a broad spectrum of GUM measurements, not just energy generation.

With broader deployment of renewable energy generation capabilities there is increasing demand for the allocation of land and construction of the related infrastructure. Photovoltaic generation requires substantial land mass, wind turbines are installed in offshore waters as well as in mountainous areas and less common installations. For example, Nevada's Ivanpah Solar Power Facility uses fields with focussing mirrors for concentrated solar power, these can be deployed in large exclusion zones, such as deserts. With the recent disruption of energy supplies seen in 2022, natural gas is sourced from various countries (not necessarily in Europe), including deliveries of liquified gas by sea. Emissions from ships are direct emissions alongside other Scope 1 transport emissions. The life cycle of all Scope 1 emissions, those produced directly by the use of fossil fuel transport systems and energy generation, need to be included and assessed for the estimation of carbon footprint of AI.

It is important that the life cycle assessment of hardware is included in the assessment of the carbon footprint of AI. This will involve tracing the supply of rare earth metals, which are not currently mined in Europe. The hardware emissions are likely to be negligible compared with the operational carbon footprint of a large language model. It is important to note that many aspects of the life cycle assessment often remain non-transparent. It is important that these transparency issues are noted in any emissions assessed.

The focus of the emissions assessment on the impact of the AI corresponds to the Scope 2 indirect emissions from operational use. These can be immediately quantified using publicly available data supplied from European national grids. The AI carbon emissions footprint needs to be quantifiable and is likely to be high impact to understand how AI deployment can be measured in a sustainable way. This is the recommended approach to measure AI deployments and can be considered responsible AI.

4.3 European energy infrastructure

There are European specific aspects of energy use for AI and there are gaps in current standardization activities which do not consider the specific energy supply. There are issues for, hydro and nuclear generation and integrated energy systems (interconnectors). These need to be considered alongside the United Nations sustainable development goals internationally, in Europe issues related to the delivery of the European Green Deal, and nationally such as the UK's Net-Zero-Carbon targets. These specific issues introduce challenges for the assessment of carbon footprint of energy generation in quantifying the energy mix used for energy delivery at the point of consumption, for example, at a data centre [9].

Figure 1 — Trans-European energy network ENTSO-E with major electrical interconnectors

International electrical connections are marked by blue lines, and international gas pipes by red lines, national and minor links are denoted by grey lines. Major interconnectors are critical to understand the cross-boundary interconnectors for energy in Europe, and the energy mix is key to assessing the energy carbon footprint of AI use.

No other continent has such a dense interconnected network of high complex energy supply that needs to be modelled appropriately to estimate the carbon footprint of AI energy use, specifically because energy is imported from outside of Europe and uses different energy sources. The European Network of Transmission System Operators for Electricity (ENTSO-E) is the association of the European transmission system operators (TSOs) representing 35 countries. The synchronous grid of Europe is the largest synchronous electrical grid (by connected power) in the world. It is an interconnected single phase-locked 50 Hz mains frequency electricity grid that supplies over 500 million customers, most of the European Union. The synchronous grid goals are sustainability, affordability and resilience, with a large number of renewables integrated into many national grids [10].

Eastern European countries rely heavily on brown coal (containing lignite rather than anthracite in black coal) for their energy supply. In France up to 75 % of electricity is generated by nuclear energy. Carbon emissions differ depending on the fuel used and the life cycle of energy used. The energy landscape in Europe is constantly changing, with varying suppliers, domestic and foreign, whose operational emissions are quantified based on the publicly available data in each European country. In the UK, the National Grid is providing 30-min fuel mix data, including interconnector data with Scandinavia, Ireland, and France [11].

AI will be instrumental in improving energy efficiency in the European Network of Trans-European Energy Network, optimizing energy use in demand-side response programmes, and supporting digital energy services.