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Telecommunication Standardization Sector

AI and the Environment - International Standards for AI and the Environment

2024 Report

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AI and the Environment - International Standards for AI and the Environment

2024 Report

Foreword

Artificial Intelligence (AI) can help optimize energy and resource efficiency and make numerous other contributions to global sustainability goals. Realizing this potential will require robust, universally accepted standards supporting environmentally responsible AI development and application.

International standards provide the guidelines and benchmarks needed to measure and improve the environmental impact of AI. Codifying established best practices, standards help mitigate risks such as high energy consumption and lifecycle emissions. They also provide measurement methodologies to assess GHG emissions and energy consumption, and thereby identify the actions needed to improve.

Achieving this vision of sustainable AI that offers powerful tools for climate action will demand close collaboration among a diverse array of stakeholders from government, industry, academia and civil society. The International Telecommunication Union (ITU) stimulates this collaboration as the United Nations specialized agency for information and communication technologies.

This report explores the environmental implications of AI and presents a summary of relevant standards available and under development. It highlights the importance of a coordinated, international approach to standardization and the need for continued engagement and cooperation across all sectors.

I extend my gratitude to all contributors to this report for sharing their insights and expertise. Together, we can ensure that AI serves as a catalyst for sustainable development, benefiting both our planet and future generations.

Seizo Onoe

Seizo Onoe
Director, Telecommunication Standardization Bureau (TSB)
International Telecommunication Union (ITU)

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Abbreviations and Acronyms

AI	Artificial Intelligence
CPU	Central Processing Unit
GHG	Greenhouse Gas Emissions
GPU	Graphics Processing Unit
ICT	Information and Communication Technology
ITU	International Telecommunication Union
SDGs	Sustainable Development Goals
SDO	Standards Development Organizations
TPU	Tensor Processing Unit
U4SSC	United for Smart Sustainable Cities

Executive Summary

This report addresses the intersection of Artificial Intelligence (AI) and environmental sustainability, emphasizing the importance of international standards in guiding the ICT industry towards an environmentally sustainable future. As AI continues to revolutionize various sectors with its transformative capabilities, it also presents significant environmental challenges. These include high energy consumption in data centres and increased greenhouse gas emissions due to the substantial computational power required for AI operations, as well as the growing problem of e-waste from rapidly advancing technology.

Understanding the lifecycle of AI is crucial when assessing its environmental impacts, as it highlights stages where energy consumption and GHG emissions can be most significant and where reductions can be made. The AI lifecycle includes several key stages: identifying the problem, data collection, designing a model, model training, model evaluation, model deployment, and inference. During these stages, particularly model training and inference, substantial computational power is required, leading to high energy consumption in data centres. This process contributes significantly to increased greenhouse gas emissions. By comprehensively understanding these lifecycle stages, it is possible to pinpoint where energy consumption and GHG emissions are most pronounced, enabling targeted actions to mitigate their environmental impact and promote sustainable AI practices.

Continuous innovation in AI and its applications is crucial for tackling global challenges, including climate change. However, without proper guidelines and standards, the environmental footprint of AI could outweigh their benefits. This report highlights the role of international standards in ensuring that AI developments are effective and sustainable.

The ICT industry stands at the forefront of this transformation. By adopting and adhering to these standards, industry players can not only enhance the environmental efficiency of their AI systems but also leverage AI as a powerful tool for climate action. Standards provide the necessary framework to measure, manage, and mitigate the environmental impacts of AI, from the product level to the network level, encompassing data centres and addressing e-waste management. The ITU-T SG5 has been producing backbone standards for the environmental efficiency of AI and other emerging technologies, ensuring a comprehensive approach to sustainability in the sector.

This document serves as an essential resource for governments and the industry and, offering comprehensive insights into the current standards landscape and ongoing efforts to improve the environmental sustainability of AI. It not only details how to build and implement sustainable practices but also emphasizes the importance of measuring progress. Accurate measurement is crucial for assessing the effectiveness of sustainability initiatives and making informed decisions to drive further improvements. The report also underscores the importance of collaboration among experts, academia, member states, and standards development organizations (SDOs) to achieve these goals. By adopting a unified approach to standardization, we can ensure that AI contribute positively to our collective goal of achieving global sustainability targets.

Introduction

Artificial Intelligence (AI), defined by the ITU as "An interdisciplinary field, usually regarded as a branch of computer science, dealing with models and systems for the performance of functions generally associated with human intelligence, such as reasoning and learning. A computerized system that uses cognition to understand information and solve problems,"[1] has evolved rapidly, becoming a significant component of modern technology, which drives innovation across various sectors. From health care and finance to transportation and manufacturing, AI is reshaping industries and enhancing productivity. However, this rapid advancement comes with significant environmental implications. As AI systems, especially those based on deep learning, require substantial computational power, they contribute to increased energy consumption and greenhouse gas (GHG) emissions. Understanding the environmental impact of AI is crucial for developing strategies that ensure sustainable growth.

The importance of establishing international standards for AI cannot be overstated. Standards play a role in ensuring that AI is developed and deployed in an environmentally sustainable manner. They provide guidelines and best practices that help mitigate the negative environmental impacts of AI, promoting energy efficiency, and reducing carbon footprints. By adhering to these standards, industries can achieve consistency, reliability and efficiency, which are crucial for addressing global environmental challenges.

This report will:

- Outline the need for international standards in AI and their role in promoting environmental sustainability.
- Explore the relationship between AI and energy consumption, discussing AI's dual role in contributing to, and potentially mitigating the effects of, greenhouse gas emissions.
- Analyse factors influencing AI's environmental efficiency, such as energy consumption, hardware efficiency, algorithmic optimization, renewable energy sources, data management and lifecycle management.
- Highlight the benefits of standardization in promoting environmentally sustainable AI and discuss the significant contributions of the International Telecommunication Union (ITU) and AI, particularly in environmental sustainability.
- Identify gaps in AI environmental standards and propose solutions to address these deficiencies, outlining ITU's ongoing and future work aimed at mitigating AI's environmental impact.

By addressing these areas, the report aims to provide a comprehensive understanding of the intersection between AI and the environment, and the role that standards play in ensuring a sustainable future.

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[1] ITU (2022). Glossary – Artificial Intelligence for Natural Disaster Management. Retrieved from https://www.itu.int/dms_pub/itu-t/opb/fg/T-FG-AI4NDM-2022-1-PDF-E.pdf

AI and the Environment

AI, particularly those of its aspects that involve large-scale data processing and machine learning, requires substantial computational power. This demand is primarily met by data centres, which house the necessary hardware and operate continuously to support AI applications. As a result, data centres consume vast amounts of energy, contributing significantly to global electricity usage. For instance, it is estimated that data centres now account for more than 1 per cent of global electricity use.[2]

The energy consumption of AI is driven by several factors. AI models, especially large-scale models like those used in natural language processing and image recognition, is extremely energy intensive. A single AI model can emit as much carbon as five cars over their lifetimes.[3] Additionally, the computational power required for AI has been doubling approximately every five to six months since 2010.[4] This rapid increase in computational demands amplifies the energy consumption and environmental impact of AI.

> *The computational power required for sustaining AI's rise is doubling roughly every 100 days. The energy required to run AI tasks is already accelerating with an annual growth rate between 26 per cent and 36 per cent. This means by 2028, AI could be using more power than the entire country of Iceland used in 2021*[5]

Beyond energy consumption, the environmental impact of AI extends to other resource demands. Generative AI systems, for instance, require significant amounts of fresh water to cool their processors and generate electricity.[6] Additionally, the cooling of data centres to maintain optimal operating conditions for the hardware, necessitates substantial water usage, which can strain local water supplies and ecosystems. This additional resource demand highlights the broader ecological footprint of AI.

To mitigate these impacts, it is essential to consider the entire lifecycle of AI. The lifecycle of AI involves several steps that ensure the development and deployment of effective models.

- The first step is to **identify the problem or the opportunity** that AI could address.
- The next step is **data collection**, where relevant data are gathered from various sources. These data are then preprocessed to clean and transform it into a suitable format for analysis.
- Once the data have been collected, it follows the **design of a model**, which involves selecting the appropriate algorithm and architecture based on the problem at hand.
- The **model is then trained** using the preprocessed data, adjusting its parameters to minimize errors.

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[2] Chow, A. (2024). How AI is fueling a Boom in Data Centers and Energy Demand. *Time*. Retrieved from https://time.com/6987773/ai-data-centers-energy-usage-climate-change/

[3] Hao, K (2019). Training a single AI model can emit as much carbon as five cars in their lifetimes. *MIT Technology Review*. Retrieved from https://www.technologyreview.com/2019/06/06/239031/training-a-single-ai-model-can-emit-as-much-carbon-as-five-cars-in-their-lifetimes/

[4] Rozite, V., Miller, J., Oh, J. (2023). Why AI and energy are the new power couple. *IEA*. Retrieved from https://www.iea.org/commentaries/why-ai-and-energy-are-the-new-power-couple

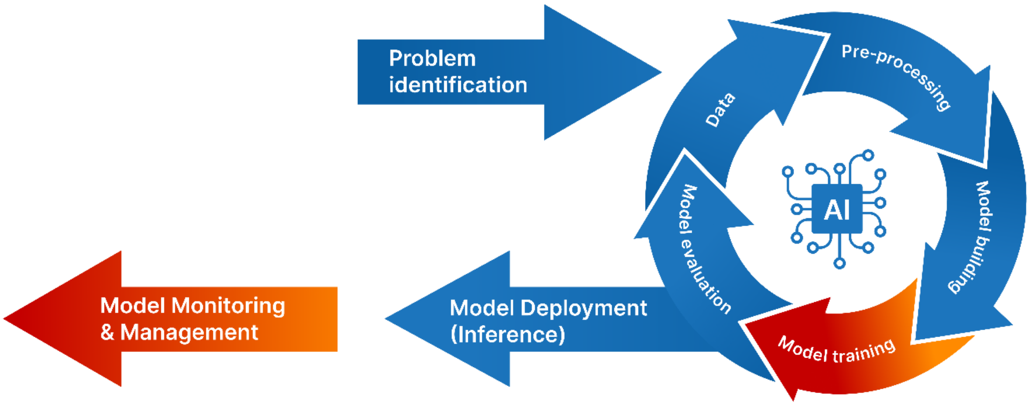
[5] Ammanath, B. (2024) How to manage AI's energy demand – today, tomorrow and in the future. World Economic Forum. Retrieved from https://www.weforum.org/agenda/2024/04/how-to-manage-ais-energy-demand-today-tomorrow-and-in-the-future/

[6] Crawford, K. (2024). Generative AI's environmental costs are soaring – and mostly secret. *Nature*. Retrieved from https://www.nature.com/articles/d41586-024-00478-x

- Following training, the **model is evaluated** and optimized to ensure it meets the desired performance criteria.
- After optimization, the **model is converted to a format suitable for deployment** in the target environment.
- The final steps are to **deploy the model and make inferences**, where the model is put into production to generate predictions or insights from new data.

An important aspect to consider throughout the AI lifecycle is model drift, which occurs when the model's performance degrades over time due to changes in the underlying data distribution. Regular monitoring and updating are essential to maintain the model's accuracy and reliability in dynamic environments.

Figure 1: Lifecycle of AI



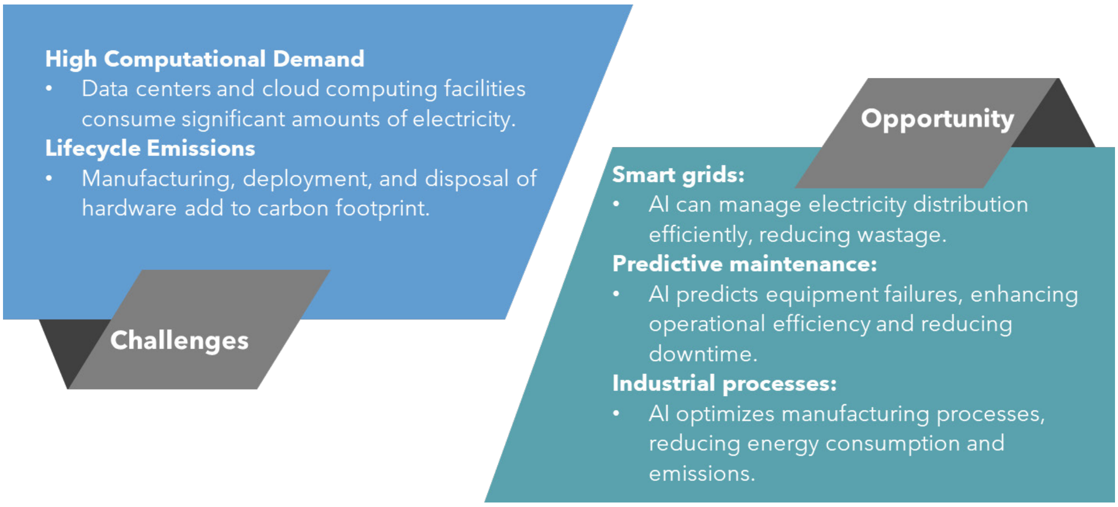
This includes the energy consumed during model training and inference and the resources used for cooling. Developing more energy-efficient algorithms, optimizing data centre operations, and transitioning to renewable energy sources are crucial steps toward reducing the environmental footprint of AI. Furthermore, implementing sustainable practices in hardware lifecycle management, such as recycling and responsible disposal of components, can help minimize e-waste and its associated environmental consequences.

By addressing these challenges, the AI industry can work towards more sustainable and environmentally friendly practices, ensuring that the benefits of AI are not overshadowed by its ecological impact. Through a combination of technological innovation and conscientious resource management, it is possible to harness the power of AI while minimizing its environmental footprint.

The Dual Role of AI in Energy Consumption and Emissions

AI holds a dual role in energy consumption and GHG emission, presenting challenges and opportunities. On the one hand, the high computational demands of AI models, particularly deep learning algorithms, lead to significant energy consumption and associated emissions. On the other hand, AI has the potential to optimize energy use and reduce GHG emissions across various sectors through innovative applications.

Figure 2: Challenges and opportunities of AI for the Environment



High Computational Demand
- Data centers and cloud computing facilities consume significant amounts of electricity.

Lifecycle Emissions
- Manufacturing, deployment, and disposal of hardware add to carbon footprint.

Challenges

Opportunity

Smart grids:
- AI can manage electricity distribution efficiently, reducing wastage.

Predictive maintenance:
- AI predicts equipment failures, enhancing operational efficiency and reducing downtime.

Industrial processes:
- AI optimizes manufacturing processes, reducing energy consumption and emissions.

Challenges

While the list below highlights some of the key environmental challenges associated with AI, it is not exhaustive and underscores the complexity of AI's environmental impact.

High Computational Demand: Data centres and cloud computing facilities that power AI models consume vast amounts of electricity. The energy required for training AI models, especially large-scale deep learning networks, is substantial. This intensive computational demand leads to increased energy consumption, often relying on non-renewable energy sources, thereby contributing to GHG emissions.

Lifecycle Emissions: The environmental impact of AI extends beyond its operational phase. Data centres include ICT goods, and the procurement (choice and purchase) of these goods determines material consumption in manufacturing, energy consumption, GHG emissions, durability in use (often with a short operational lifespan due to performance requirements), and re-use phases and e-waste production. The manufacturing, deployment, and disposal of hardware necessary for AI systems, such as GPUs, TPUs, and other specialized processors, contribute significantly to the overall carbon footprint. This lifecycle of AI hardware includes emissions from the extraction of raw materials, production processes, transportation, and eventual e-waste management.

Opportunities

The list below highlights some of the key opportunities for AI to support sustainability, but it is not exhaustive and underscores the vast potential of AI to contribute to a more sustainable future.

Smart Grids: AI can play a transformative role in managing electricity distribution efficiently through smart grids. By analysing consumption patterns and predicting demand, AI systems can optimize the distribution of electricity, reducing wastage and enhancing the integration of renewable energy sources. This optimization can lead to a more stable and efficient energy grid, minimizing energy loss and lowering GHG emissions.

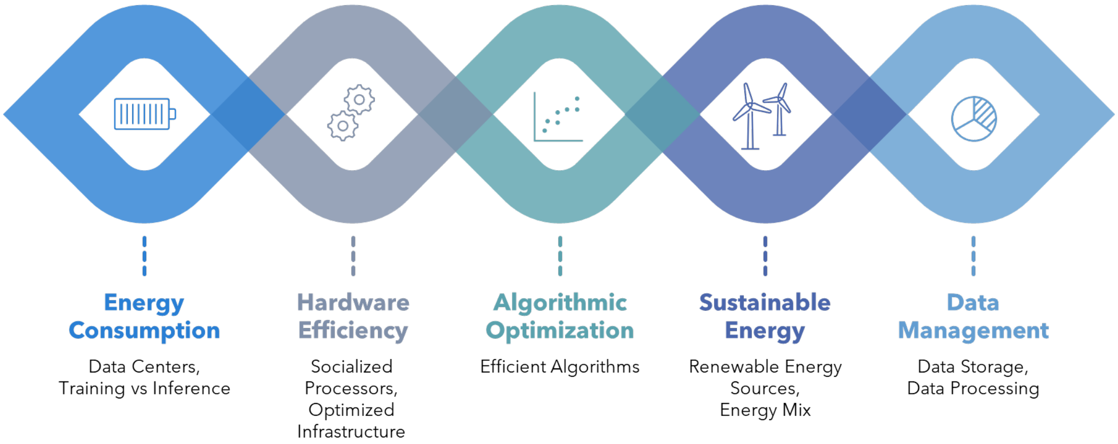
Predictive Maintenance: AI-driven predictive maintenance can significantly enhance operational efficiency in various industries. By predicting equipment failures and scheduling timely maintenance, AI systems reduce downtime and energy waste. This not only improves the longevity and performance of machinery but also contributes to lower energy consumption and emissions associated with unexpected equipment breakdowns.

Industrial Processes: AI can optimize manufacturing processes, leading to reduced energy consumption and emissions. Through techniques such as real-time monitoring and adaptive control, AI systems can identify inefficiencies and implement corrective actions to minimize energy use. This optimization of industrial processes not only reduces operational costs but also lowers the environmental impact of manufacturing activities.

AI Environmental Efficiency Factors

Several key factors influence the environmental efficiency of AI systems, each playing a crucial role in determining the overall sustainability of AI.

Figure 3: Key Factors of the environmental efficiency of AI systems



Energy Consumption

Data Centres: AI models, particularly deep learning algorithms, demand substantial computational power, resulting in significant energy consumption within data centres. This energy demand is primarily due to the extensive processing required for training large models, which involves running numerous computations over massive datasets.

Training vs. Inference: The training phase of AI models is especially energy-intensive compared to the inference phase, where the trained model is used for making predictions. Training involves numerous iterations and adjustments to the model's parameters, requiring a considerable number of computational resources and, consequently, energy.

Hardware Efficiency

Specialized Processors: Utilizing specialized hardware, and other AI accelerators can enhance computational efficiency, thus reducing energy consumption. These processors are designed to handle the parallel processing demands of AI workloads more effectively than traditional CPUs. However, the fast evolution of computational performance demand can make these processors obsolete very quickly compared to their operational lifespan. Plans for re-use after replacement in less demanding tasks can keep these processors in use to prevent short-lived computing elements with an important material footprint in manufacturing and e-waste generation.

Optimized Infrastructure: Energy efficiency can also be improved using energy-efficient servers and the optimization of data centre cooling systems. Implementing advanced cooling technologies and optimizing server utilization can significantly reduce the overall energy footprint of AI operations.

Algorithmic Optimization

Efficient Algorithms: Developing more efficient algorithms that require less computational power can markedly decrease energy consumption. Techniques such as model pruning, which reduces the size of AI models by removing unnecessary parameters, quantization, which reduces the precision of the models' calculations, and knowledge distillation, which transfers knowledge from larger models to smaller ones, help in making AI models more energy efficient.

Sustainable Energy

Renewable Energy Sources: Powering data centres and computational infrastructure with renewable energy sources, such as solar, wind, or hydroelectric power, can significantly reduce the carbon footprint of AI operations. Transitioning to renewable energy helps in offsetting the substantial energy demands of AI with sustainable power.

Energy Mix: Incorporating a higher percentage of low-carbon energy sources into the overall energy mix used for AI infrastructure can also contribute to reducing greenhouse gas emissions. Balancing the energy portfolio with a mix of renewable and low-carbon sources ensures a more sustainable approach to powering AI.

Data Management

Data Storage: Efficient data storage solutions that minimize redundancy and employ energy-saving technologies are crucial for reducing the environmental impact of AI. Implementing data deduplication and energy-efficient storage hardware can lower the energy required for data storage.

Data Processing: Optimizing data processing pipelines to reduce computational load can significantly enhance energy efficiency. Streamlining data processing workflows and implementing efficient data management practices are essential steps in this direction. Embracing the concept of data sobriety – focusing on processing only the necessary data, avoiding unnecessary data collection and storage, and prioritizing lean data practices – can further minimize the energy consumed during data handling and analysis. This approach not only conserves energy but also reduces the overall environmental impact of data-intensive AI operations.

Lifecyle Management

Environmental Sustainability: Considering the environmental impact at each stage of AI system development, from research and development to deployment and decommissioning, is important for sustainability. Digital product information, such as a digital product passport, can facilitate the selection of optimal computing elements and ICT goods based on their technical and environmental specifications, including precise environmental values in inventory management, and facilitating optimized replacement, re-use and recycling decisions.

Recycling and Disposal: Proper recycling and disposal of hardware components at end of life are essential for minimizing electronic waste (e-waste). Implementing responsible e-waste management practices and ensuring that components are recycled or disposed of correctly can mitigate the environmental impact of AI hardware.

The Importance of Standards for AI and the Environment

Standardization is important in ensuring that AI is developed and deployed in an environmentally sustainable manner. Standards provide guidelines and benchmarks for energy efficiency, hardware optimization, and sustainable data management practices. They help harmonize efforts across different stakeholders, ensuring consistency and reliability.

Standardization involves creating consensus-based guidelines and benchmarks that govern the development and deployment of technologies. In the context of AI, standards can cover various aspects, including ethical considerations, security, interoperability, and environmental sustainability.

Benefits of standardization for AI and Sustainability

Guidance for Best Practices: Standards provide a framework for implementing best practices in AI development and deployment, ensuring that environmental considerations are integrated into the design and operation of AI systems.

Consistency and Reliability: By adhering to standardized guidelines, AI developers and operators can ensure that their systems meet specific environmental performance criteria, such as energy consumption and GHG emissions. This focus on measurement and measurable impacts promotes more consistent and reliable outcomes, facilitating accurate assessment and improvement of environmental performance.

Market Trust and Adoption: Standards build trust in AI technologies by demonstrating a commitment to sustainability. This can drive wider adoption of AI solutions that are environmentally friendly, contributing to broader sustainability goals.

Despite the benefits, there are gaps in the current standards that need to be addressed. For example, there is a lack of comprehensive metrics for measuring the energy efficiency of AI systems, and guidelines for lifecycle assessment are not yet fully developed. Addressing these gaps is essential for realizing the full potential of standardization in promoting sustainable AI.

Standardization efforts and the role of ITU

The International Telecommunication Union (ITU) plays an important role in the development of global standards for artificial intelligence (AI). As a specialized agency of the United Nations, ITU is responsible for ensuring that AI is developed and deployed in a way that promotes interoperability, safety, and sustainability across various sectors. By establishing international standards, ITU helps to create a harmonized framework that guides the implementation of AI solutions worldwide. The organization's efforts span multiple domains, each with specific requirements and challenges.

These standards encompass various domains, including technical specifications for AI systems, cloud platforms, AI-enabled vehicle systems, medical devices, telecom operations, and smart sustainable cities. ITU's work ensures that AI can efficiently leverage cloud resources, enhance vehicle communication and safety, revolutionize health care with AI-powered devices, optimize telecommunication networks, and contribute to urban sustainability through intelligent infrastructure. By addressing data privacy, cybersecurity, and environmental efficiency, ITU promotes confidence in AI and ensures their safe, reliable, and sustainable integration into diverse applications. One of ITU's areas of focus is the environment and sustainability, ensuring that the rapid advancement of technology does not come at the expense of our planet. Central to this mission is ITU-T Study Group 5 (SG5) on Environment, EMF and Circular Economy, which is dedicated to creating standards that address environmental and climate change issues related to ICTs, including AI.

Within ITU, ITU-T Study Group 5 is dedicated to developing standards for environmental and climate change mitigation, including those related to AI. This group focuses on creating guidelines and benchmarks that promote the environmental sustainability of AI.

ITU-T Study Group 5 plays an important role in ensuring that AI are developed and deployed in environmentally responsible ways. SG5 has been instrumental in producing standards that promote energy efficiency, minimize carbon footprints, and facilitate the circular and sustainable use of resources. Their work includes guidelines for the deployment of AI in smart cities, energy-efficient data centres, and environmentally friendly telecommunications infrastructure. By developing these standards, SG5 supports the development of AI in ways that enhance environmental sustainability and resilience.

Get Involved in Shaping Global Standards

ITU Standards, also called "Recommendations" are developed through the collaboration of countries, industry leaders, and academia, ensuring they reflect diverse perspectives and needs. Your expertise and insights can drive the development of standards that promote sustainability and innovation. Join ITU-T Study Group 5's efforts by contributing knowledge and helping to create a smarter, and more sustainable future.

AI and International Standards for the environment

When it comes to AI, standards can be categorized into two main types: backbone standards for environmental efficiency and standards that support AI as an enabler for climate action. Backbone standards focus on the environmental efficiency of AI systems, addressing fundamental aspects such as product level, site level, and network level efficiency. These standards provide the essential framework for measuring and improving the environmental impact of AI. They include guidelines for optimizing hardware, data centres, and network infrastructure to reduce energy consumption and emissions.

On the other hand, AI for climate solutions standards is designed to help various sectors implement AI-driven practices that contribute to energy reduction and broader climate goals. These standards guide the application of AI in areas such as green data centres, energy efficiency measures, and data management, that enable sectors to leverage AI for achieving significant environmental and climate benefits. Together, these standards ensure that AI is environmentally efficient and effectively utilized in climate action initiatives.

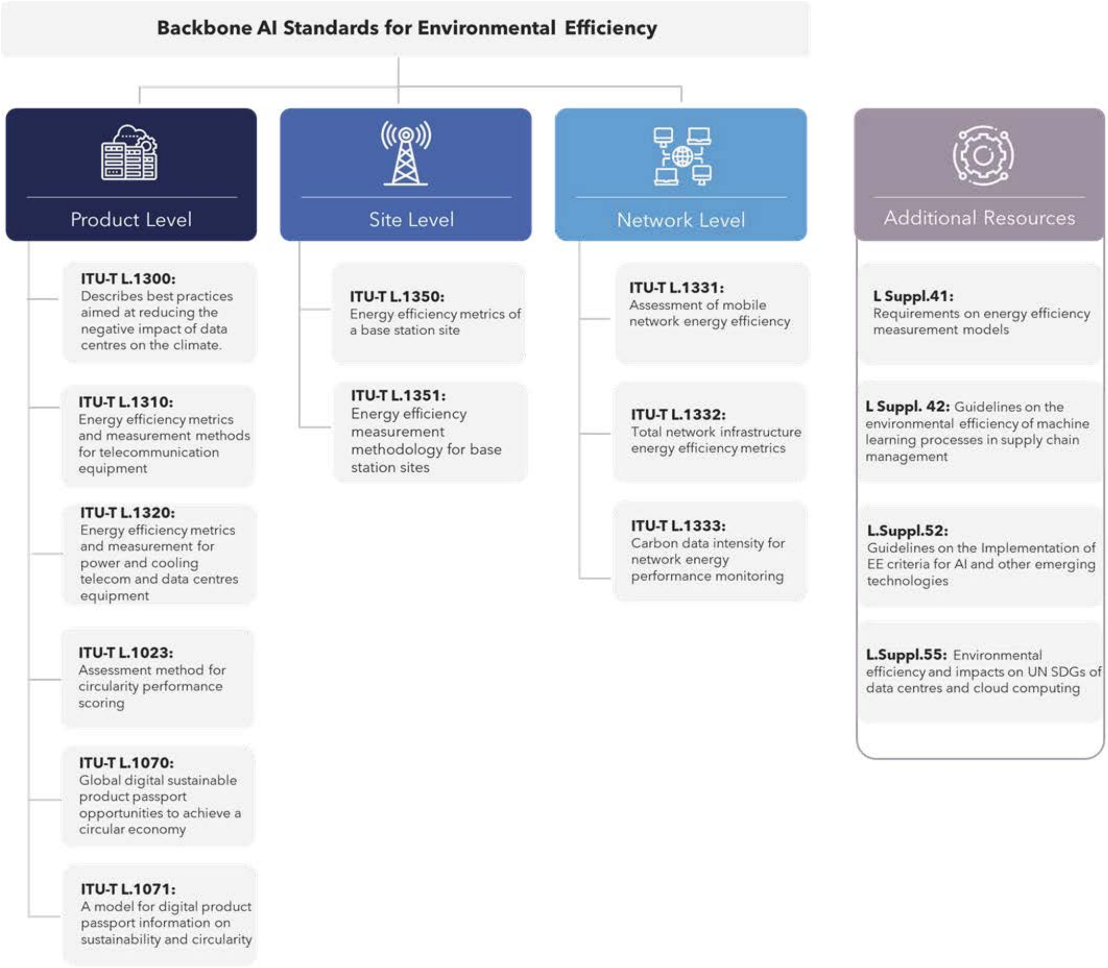
Figure 4: Standards for AI and the environment

Backbone Standards for Environmental Efficiency

These fundamental standards are crucial for assessing and enhancing the sustainability of AI throughout their lifecycle. These standards focus on several key levels:

- **At the product level**, they address the environmental impact of telecommunication equipment, power and cooling systems for telecom and data centres, circularity performance scoring, energy-saving technologies, and digitalized product information (product passports) for the many diverse ICT products involved in a data centre.
- **At the site level**, they concentrate on improving energy efficiency and measuring performance in base stations.
- **At the network level**, standards evaluate mobile network energy efficiency and carbon data intensity for monitoring network performance.
- **Additional resources**, these technical reports encompass topics such as supply chain management, alignment with UN Sustainable Development Goals (SDGs), and the environmental impact of data centres and cloud computing.

Figure 5: Backbone AI Standards for Environmental Efficiency



Product Level

ITU-T L.1300: Describes best practices aimed at reducing the negative impact of data centres on the climate.

ITU-T L.1310: Energy efficiency metrics and measurement methods for telecommunication equipment

ITU-T L.1320: Energy efficiency metrics and measurement for power and cooling telecom and data centres equipment

ITU-T L.1023: Assessment method for circularity performance scoring

ITU-T L.1070: Global digital sustainable product passport opportunities to achieve a circular economy

ITU-T L.1071: A model for digital product passport information on sustainability and circularity

Site Level

ITU-T L.1350: Energy efficiency metrics of a base station site

ITU-T L.1351: Energy efficiency measurement methodology for base station sites

Network Level

ITU-T L.1331: Assessment of mobile network energy efficiency

ITU-T L.1332: Total network infrastructure energy efficiency metrics

ITU-T L.1333: Carbon data intensity for network energy performance monitoring

Additional Resources

L Suppl.41: Requirements on energy efficiency measurement models

L Suppl. 42: Guidelines on the environmental efficiency of machine learning processes in supply chain management

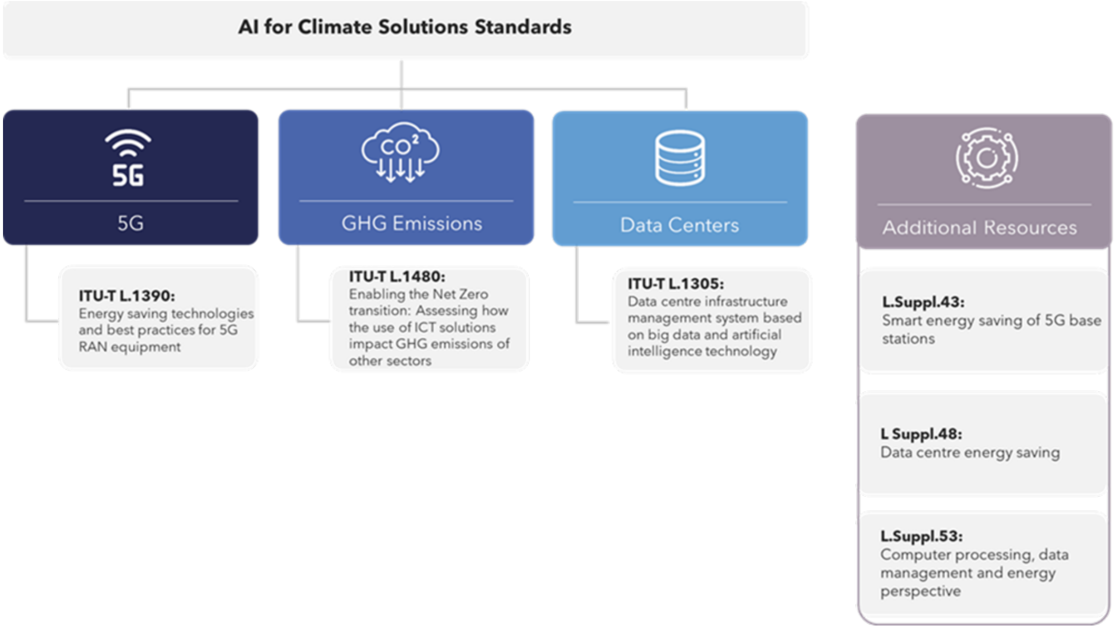
L.Suppl.52: Guidelines on the Implementation of EE criteria for AI and other emerging technologies

L.Suppl.55: Environmental efficiency and impacts on UN SDGs of data centres and cloud computing

AI for Climate Solutions Standards

AI for Climate Action Standards are designed to guide the application of AI in advancing climate goals. These standards provide a framework for leveraging AI to drive significant environmental benefits, such as optimizing energy use and supporting climate action initiatives. They focus on integrating AI into practices that enhance energy efficiency, in data centres therefore reducing energy consumption and emissions. By following these standards, sectors can effectively utilize AI to contribute to global climate efforts, advancing sustainability and helping to address pressing environmental challenges.

Figure 6: AI for Climate Solutions Standards



ITU-T L.1390: Energy saving technologies and best practices for 5G RAN equipment

ITU-T L.1480: Enabling the Net Zero transition: Assessing how the use of ICT solutions impact GHG emissions of other sectors

ITU-T L.1305: Data centre infrastructure management system based on big data and artificial intelligence technology

L.Suppl.43: Smart energy saving of 5G base stations

L Suppl.48: Data centre energy saving

L.Suppl.53: Computer processing, data management and energy perspective

Ongoing Work that Supports AI and the Environment

The International Telecommunication Union (ITU) continues to spearhead initiatives that address the environmental impact of AI and other emerging technologies. ITU's ongoing efforts are focused on developing comprehensive standards and frameworks to ensure the sustainable deployment of AI.

Several key activities currently underway include:

Figure 7: Ongoing ITU Work on AI and the Environment

Energy Consumption Management and Optimization Platform Framework for Cloud Computing (L.FCC)

This Recommendation aims to provide a technical framework and requirement for energy consumption management and optimization of cloud computing service.

Guidelines on Multi-Dimensional Environmental Metrics and Management for Data Centres (L.Env_DC)

This Recommendation will comprehensively evaluate the environmental impact of data centres and manage the metrics to guide data centres to further promote the green development of data centres under the carbon neutral goals.

High Efficiency Liquid Cooling Solutions and Practices for Data Centres (L.liquid_DC)

This Recommendation identifies the current business changes in data centres and their impact on supporting infrastructure, proposes the comparison between air cooling and liquid cooling technologies.

Computing Power Efficiency Matrix and Measurement Methodology (L.MM_Computing_power)

The objective of this Recommendation is to make clear the computing power efficiency matrix and measurement methodology and promote the widely use on artificial intelligence data center, Supercomputing data center in the future.

Guidelines for the Assessment of the Carbon Footprint of Software Products (L.CFSP)

The Recommendation will help stakeholders to comprehensively understand their carbon emissions and to identify key emission reduction strategies during the overall life cycle of software products.

Guidelines for Assessing the Impact of AI on GHG Emissions (L.ClimAI)

This Recommendation provides a holistic framework for evaluating the greenhouse gas emissions of artificial intelligence, covering direct and indirect impacts, assessment, and mitigation strategies.

Energy Saving Strategy for Deep Learning Computing (L.IEDL)

This Recommendation identifies strategies and best practice when and how technologies should be used in deep learning AI computing thereby reducing the AI computing center or AI computing platform system energy consumption.

Deep Learning Computing Energy Efficiency Evaluation Framework and Metrics (L.DLEE)

The Recommendation aims to develop metrics and evaluation methods to assess energy consumption across diverse models and tasks as it relates to computing efficiency of deep learning computing.

Recommendation for the design of environmentally sustainable AI-based and XR-based Systems (L.S_AI)

This Recommendation aims to provide a clear definition and outline design criteria for environmentally sustainable AI-based and XR-based systems

Testing and Assessment Method of Green Computing Power (L.TR_TA_GC)

This technical report aims to provide a framework for computing power assessment, quantitative analysis of computing power energy conservation and consumption reduction and achieve measurable computing power testing of environmental aspects.

Measurement Methods for Energy Consumption of the Domain Name System (DNS) in Distributed Data Centres (L.TR_MS_DS)

This technical report aims to ensure that the energy usage of DNS operations is accurately measured and optimized, contributing to the overall energy efficiency of data center infrastructure.

These ongoing activities by ITU highlight its commitment to addressing the environmental challenges posed by AI and other emerging technologies. Through the development and implementation of these standards, ITU aims to advance a sustainable and resilient technological landscape.

- More information on the ongoing work of ITU-T SG5 please visit: https://www.itu.int/ITU-T/workprog/wp_search.aspx?sg=5
- More information on the ITU-T SG5 approved standards please visit: https://www.itu.int/ITU-T/recommendations/index_sg.aspx?sg=5

Initiatives Driving AI and Sustainability

As the impact of AI on our world continues to grow, ensuring its development and deployment are aligned with environmental sustainability becomes increasingly more important. Several initiatives have been established to address this imperative, focusing on the integration of AI with sustainable practices.

ITU Focus Group on Environmental Efficiency for Artificial Intelligence and Other Emerging Technologies (FG-AI4EE)

ITU established and concluded the Focus Group on Environmental Efficiency for Artificial Intelligence and Other Emerging Technologies (FG-AI4EE), which has produced 21 accepted deliverables. This group aimed to identify the standardization needs to develop a sustainable approach to AI and other emerging technologies including automation, augmented reality, virtual reality, extended reality, smart manufacturing, industry 5.0, cloud/edge computing, nanotechnology, 5G, among others.

The Focus Group has produced numerous publications to guide stakeholders in implementing sustainable AI practices. These publications provide comprehensive frameworks and best practices for leveraging AI in ways that support environmental sustainability and align with global sustainability goals.

Figure 8: Key Deliverables Published on AI and the Environment

Smart Sustainable Cities

FG-AI4EE-D.WG2-04
Showcasing successful implementations of AI in enhancing the sustainability of urban environments.

FG-AI4EE D.WG1-10
Leveraging digital twin technology to develop effective climate change solutions in cities.

FG-AI4EE D.WG1-06
Framework for integrating AI technologies into smart city infrastructures to enhance sustainability.

FG-AI4EE D.WG1-11
Guidelines for creating and utilizing digital twins to manage and optimize city resources effectively.

AI and Sustainability

FG-AI4EE-D.WG1-08
Strategies for aligning AI and IoT designs with the United Nations' Sustainable Development Goals.

FG-AI4EE D.WG1-04
Metrics for small and medium enterprises to measure their progress towards sustainable development objectives.

FG-AI4EE-D.WG1-02
Evaluating business processes to ensure they are environmentally friendly and promote sustainable behaviors.

FG-AI4EE D.WG2-06
Guidelines for evaluating the environmental efficiency of data centers and cloud services in relation to the SDGs.

Energy Efficiency and Management

FG-AI4EE D.WG3-02
Utilizing AI to optimize the energy consumption of 5G networks and reduce operational costs.

FG-AI4EE D.WG2-03
Requirements and models for measuring energy efficiency, leveraging AI and big data.

FG-AI4EE D.WG2-05
Best practices for implementing blockchain technology in an energy-efficient manner.

FG-AI4EE D.WG3-03
Applying AI to improve the energy efficiency of telecom equipment and data center infrastructures.

Environmental Efficiency in AI Processes

FG-AI4EE D.WG3-01
Implementing environmentally friendly criteria in the development and deployment of AI technologies.

FG-AI4EE D.WG3-07
Best practices for ensuring machine learning processes in supply chain management are environmentally efficient.

FG-AI4EE D.WG2-02
Evaluating the environmental impact of data management and processing activities.

Reporting and Methodology

FG-AI4EE D.WG1-05
Standardized templates for reporting on AI, augmented reality, and machine learning initiatives.

FG-AI4EE-D.WG1-01A
comprehensive glossary of terms related to AI and environmental efficiency, promoting clarity and consistency.

FG-AI4EE D.WG1-09
Methods for enhancing human interaction with AI and machine learning data models to improve usability and accessibility.

United for Smart Sustainable Cities (U4SSC)

The United for Smart Sustainable Cities (U4SSC) initiative, a global platform coordinated by ITU, UNECE, and UN-Habitat, and supported by 16 UN Agencies, focuses on enhancing urban sustainability through smart technologies. Within U4SSC, a Thematic Group dedicated to AI and cities has been established to explore the role of AI in creating smarter, more sustainable urban environments.

One of the significant outputs of this group is the publication titled "Guiding Principles for Artificial Intelligence in Cities." This document offers a set of principles designed to help city planners, policymakers, and other stakeholders integrate AI into urban planning and management effectively, ensuring that AI applications contribute to sustainable and resilient urban development.

The U4SSC Deliverable on Guiding principles for artificial intelligence in cities provides a broad set of suggested principles, enablers, governance methods, policy instrument alternatives and a simple methodology for instilling AI principles in cities.

The U4SSC Deliverable is complemented by the following case studies:

Case study – Hong Kong [Read online]
Case study – Dubai [Read online]
Case study – Buenos Aires [Read online]
Case study – Singapore [Read online]
Case study – Copenhagen [Read online]

United 4 Smart Sustainable Cities

Guiding principles for artificial intelligence in cities

AI for Good

AI for Good, an initiative led by ITU in partnership with 40 UN agencies, serves as a global platform to accelerate the use of AI to tackle the world's most pressing challenges, including environmental sustainability.

With a focus on AI and the environment, AI for Good hosts sessions and workshops year-round, bringing together AI experts, industry leaders, and policymakers to discuss and develop AI solutions for environmental efficiency. Recently, they published a report on "AI Governance Day – From Principles to Implementation," which mentions intersection between AI governance and environmental sustainability.

At ITU's AI for Good Global Summit, government leaders, policymakers, researchers, and technologists from both developed and developing countries came together at the first-ever "AI Governance Day – From Principles to Implementation" on 29 May 2024.

AI Governance Day - From Principles to Implementation

2024 Report

One of the notable sessions dedicated to this topic is focused on "AI and Environmental Efficiency." This session addresses how AI can be harnessed to enhance energy efficiency, reduce waste, and support broader sustainability goals. It highlights successful case studies, emerging technologies, and the role of international standards in promoting sustainable AI practices. Additionally, AI for Good organizes yearly challenges that unite people in addressing the most pressing challenges of AI, furthering its commitment to accelerating sustainable and impactful AI solutions.

Green Digital Action

ITU-convened and partner-led, Green Digital Action aims to enhance collaboration, fast-track industry-wide commitments to addressing climate challenges, and put digital solutions at the forefront of climate action. This includes leveraging standards for climate action through the Green Standards pillar. This work sees private and public sector stakeholders collaborating to ensure that digital solutions are built using environmentally sustainable standards from the start.

Speaking on the importance of green standards at the COP28 in November 2023 in Dubai, UAE, the World Standards Cooperation, comprised of IEC, ISO and ITU, stressed that:

As the world's leading developers of international standards, we pledge to uphold the principles that allow sustainability to be built into their development by design, and to delivering the standards that make business and environmental sense.

Figure 9: GDA Call to Action and Statement

Green Digital Action @COP28

Green Digital Action aims to **enhance collaboration, fast-track industry-wide commitments** to addressing climate challenges, and put **digital solutions** at the forefront of **climate action**.

Green Standards:

Call to Action
From Commitment to action: Implementing Standards for a sustainable future

Action Plan and launch of a peer-learning working group to strengthen industry and country collaboration on the implementation of **environmental sustainability standards.**

Statement by the World Standards Cooperation
COP 28, Dubail UAE

As the world's leading developers of international standards, we pledge to uphold the principles that allow sustainability to be built into their development by design, and to delivering the standards that make both business and environmental sense.

In addition to the commitment on green standards, GDA partners also committed to:

1) Setting (or already have set) 1.5 degree aligned science-based targets.
2) Contributing to an ICT sector database creation on products and services. The development of the methodology of this database is being carried out by ITU-T SG5.
3) Reporting data on all GHG emission scopes and categories yearly and submitting results to a public ITU database.

Given the ICT sector's commitment to reducing its emissions and prioritizing environmentally sustainable AI, a new GDA pillar has been established. This initiative aims to address the GHG emissions and energy consumption of AI by bringing these crucial topics to the forefront at COP29 in November 2024, in Baku, Azerbaijan, working closely with ITU-T SG5 and other existing ITU initiative on AI and environment.

Conclusion

As AI advances rapidly, its potential to transform industries and societies is significant. However, this progress comes with a pressing need to address the environmental impact of AI. The dual role of AI – as a significant consumer of energy and a contributor to GHG emissions – highlights the importance of integrating sustainability into AI development and deployment.

Standards are crucial in guiding this integration, ensuring that AI systems are not only innovative but also environmentally responsible. By addressing key areas such as product efficiency, site operations, network performance, and resource management, these standards lay the groundwork for reducing the environmental footprint of AI. Concurrently standards can also enable the strategic application of AI to support and accelerate climate goals, optimizing energy use and enhancing resilience through advanced solutions.

Looking ahead, the effective implementation of these standards will help in shaping a future where AI contributes positively to technological advancement and sustainable development.

Appendix – List of approved and ongoing deliverables on AI and the Environment

Backbone Standards for Environmental Efficiency

Number	Title	Scope	Category
ITU-T L.1310	Energy efficiency metrics and measurement methods for telecommunication equipment	This Recommendation specifies the principles and concepts of energy efficiency metrics and measurement methods for telecommunication network equipment and for small networking equipment used in the home and small enterprise locations.	Product level
ITU-T L.1320	Energy efficiency metrics and measurement for power and cooling equipment for telecommunications and data centres	This Recommendation specifies principles and concepts of energy efficiency metrics and measurement methods for power feeding equipment and cooling equipment in telecommunications rooms and data centres. The methodologies defined in this Recommendation are applied at single equipment level. The efficiency of power conversion and cooling in the data centre or telecommunication facility is only partially attributed to the equipment. The architecture and organization of the space and equipment to deliver the power or cooling to the systems is as equal, if not a more significant factor in energy efficiency. Another general factor is the interoperability, management and response of these systems across the demand and operational range.	Product level
ITU-T L.1390	Energy saving technologies and best practices for 5G radio access network (RAN) equipment	This Recommendation identifies energy saving potentials, describes energy saving principles and technologies for 5G RAN and related equipment, and provides best practice recommendations on when and how these technologies should be used and controlled to reduce 5G RAN energy consumption.	Product level

(continued)

Number	Title	Scope	Category
ITU-T L.1023	Assessment method for circularity performance scoring	Realization of the circular economy requires incorporating elements in product design that support the reduction of material use, re-use, recycling and recovery of products, product parts, components and materials to circulate them in the value chain for as long as possible. This Recommendation contains a three-step methodology to identify an information and communication technology (ICT) good's circularity in three dimensions via three circularity aspects: first, the ICT good durability; second, the ICT good ability to be recycled, repaired, re-used and upgraded; and third, the manufacturers' ability to recycle, repair, re-use and upgrade the ICT good put into the market. The three aspects are then divided into indicators for circular product design. The circularity indicators are then assessed at four levels: from how well circularity has been achieved; the margin of improvement; and the relevance and applicability of each indicator for the ICT good at hand. The margin of improvement (MI) score and relevance score are then combined and translated into a score for each indicator. The average of applicable indicators for each circularity aspect are calculated as the total circularity score for each circularity aspect. This Recommendation is intended for the circularity assessment of a single product (e.g., phones, computers, servers, chassis, boards, modules) at a time. Whereas circularity assessment of whole equipment systems – and of organizations' overall circularity performance based on, for example, shipped products per year – are out of scope of this Recommendation.	Product level

(continued)

Number	Title	Scope	Category
ITU-T L.1300	Best practices for green data centres	This Recommendation specifies best practices aimed at developing green data centres. A green data centre can be defined as a repository for the storage, management, and dissemination of data in which the mechanical, lighting, electrical and computer systems are designed for maximum energy efficiency and minimum environmental impact. The construction and operation of a green data centre includes advanced technologies and strategies. The Recommendation provides a set of rules to be referred to when undertaking improvement of existing data centres, or when planning, designing or constructing new ones. The proposed best practices cover: data centre utilization, management and planning; ICT equipment and services; cooling; data centre power equipment; data centre building; monitoring. The environmental impact of a data centre should be assessed in line with [ITU-T L.1400], [ITU-T L.1410] and [ITU-T L.1420].	Product level
ITU-T L.1350	Energy efficiency metrics of a base station site	This Recommendation specifies principles and concepts of energy efficiency metrics used to evaluate the energy efficiency of a base station site considering the energy consumption for: the telecom equipment inside the base station site e.g., backhaul and base station equipment; the entire infrastructure, including cooling systems, monitoring systems (e.g., for power consumption, equipment running status, environment parameters), fire protection and lighting systems for all the sites; energy losses due to AC/DC rectifiers, generators and cable losses.	Site level
ITU-T L.1351	Energy efficiency measurement methodology for base station sites	This Recommendation is applicable to base station site energy efficiency parameter measurement in line with the metric established by [ITU-T L.1350]. This Recommendation describes how to realize measurement of parameters establishing requirements on: measurement points, measurement conditions, and instrumentation. This Recommendation also considers continuous monitoring of the site energy efficiency parameters. It does not specify metrics, but refers to the metric defined in [ITU-T L.1350]. The concepts of energy efficiency are covered by [ITU-T L.1315].	Site level

(continued)

Number	Title	Scope	Category
ITU-T L.1331	Assessment of mobile network energy efficiency	This Recommendation aims to provide a better understanding of the energy efficiency of mobile networks in particular considering the networks' evolution in different periods of time. The focus of this Recommendation is on metrics for energy efficiency and methods of assessing (and measuring) energy efficiency in operational networks. This Recommendation defines the topology and level of analysis needed to assess energy efficiency. The analysis includes radio base stations, backhauling systems, radio controllers (RCs) and other infrastructure radio site equipment. The technologies involved are global system for mobile communication (GSM), universal mobile telecommunications service (UMTS), long term evolution (LTE) and 5G New Radio (NR). Aiming to also consider the slicing approach of the networks from 5G onwards, the metrics are extended to the latency of the network itself versus the energy consumed, in addition to the metrics based on traffic and on coverage, already existing for legacy networks that are still valid. Both homogeneous and heterogeneous networks are considered, whose size and scale could be defined by topologic, geographic or demographic boundaries. An example of a network defined by topologic boundaries consists of a control node (whenever applicable), its supported access nodes and related network elements. Networks could also be defined by geographic boundaries, such as city-wide, national or continental, or they could be defined by demographic boundaries, such as urban or rural networks. This Recommendation also applies to so-called "partial" networks, for which a measurement method is also recommended. The specification extends the measurements made in partial networks to the wider, so-called "total" network energy efficiency estimation, such as the network in a geographical area, the network in an entire country or the network of a mobile network operator (MNO). Terminal (end-user) equipment is outside the scope of this Recommendation and is not considered in the energy efficiency measurement.	Network level

(continued)

Number	Title	Scope	Category
ITU-T L.1332	Total network infrastructure energy efficiency metrics	This Recommendation specifies principles and concepts of energy efficiency metrics and measurement methods to evaluate the energy efficiency of an entire network consisting of telecommunication equipment and infrastructure equipment. This Recommendation also develops the methodology to consider the influence on total energy consumption including maintenance activities; by establishing methodologies which consider the energy necessary for the transport activities embedded in the maintenance phase. Energy sources of different natures are taken into account in this Recommendation. For concepts of energy efficiency, see [ITU-T L.1315].	Network level
ITU-T L.1333	Carbon data intensity for network energy performance monitoring	This Recommendation defines a KPI for the carbon emission intensity of a network focused on network energy consumption in relation to data traffic. It includes the KPI definition and describes the KPI calculation and methods of measurement of the quantities necessary to calculate the KPI. The reporting of GHG emissions related to conformity or reporting in relation to [b-ITU-T L.1470] are outside the scope of this Recommendation, as are other related KPIs of potential interest. A complete assessment of lifecycle network GHG emissions is considered by Recommendation [b-ITU-T L.1410]. The network carbon intensity energy KPI is applicable to a complete network greenness assessment. It encourages not only the reduction of network electricity consumption, but also the use of low-carbon energy supply and the improvement of energy utilization efficiency. This Recommendation considers only the network operation phase, i.e., network energy consumption. The Recommendation is applicable to the public telecom network (PTN), non-public network (NPN) and enterprise network. This first edition of this Recommendation refers to data traffic intensities; however, future editions may include other metrics to describe services, such as the number of user connections.	Network level

(continued)

Number	Title	Scope	Category
ITU-T L.Suppl.41	Requirements on energy efficiency measurement models and the role of artificial intelligence and big data	Energy efficiency is a crucial issue for the sustainability of cities, today and in the future, especially due to the emerging appearance of smart cities (SC) and of cutting-edge technologies. Some emerging technologies, such as artificial intelligence (AI), big data, edge computing and cryptocurrency may not take sustainability into consideration during their development. These technologies often require a huge amount of energy, resulting in significant environmental footprints. It is important to understand how to enhance the energy efficiency of these technologies in the urban space, and to think of means to reduce the environmental footprint of these technologies. In this regard, the definition of an appropriate model that can evaluate the energy efficiency of these emerging technologies is crucial, especially within the urban space and under the lens of standardization requirements. More specifically, these technologies have to comply with the requirements of a city's energy system and with the planning for the city's sustainable future. Thus, this Supplement aims to investigate appropriate models to evaluate urban energy efficiency with a special focus on the emerging adoption of AI and big data.	Supplement
ITU-T L.Suppl.42	Guidelines on the environmental efficiency of machine learning processes in supply chain management	This guidance document is intended to support machine learning (ML) researchers and operators to measure and improve the environmental efficiency of ML, artificial intelligence (AI) and other emerging technologies use in supply chain management. The requirements, recommended processes, best practices and other considerations regarding the measurement and verification of environmental impact/efficiency contained in this document are developed based on inputs from leading academic experts and industry leaders. These requirements provide general guidelines applicable to the use of ML, AI and other emerging technologies in supply chain management. Other stakeholders may also utilize this guidance to gain new understanding on the environmental impacts of ML, AI and other emerging technologies use in supply chain management.	Supplement

(continued)

Number	Title	Scope	Category
ITU-T L.Suppl.52	Computer processing, data management and energy perspective	This Supplement presents a set of well-adopted energy efficiency practices for cyber-physical system classes and applications – enabled by artificial intelligence (AI), big data, Internet of Things (IoT), and other innovative technologies. To do so, a set of relevant and significant use cases are first introduced; Secondly, system classes are identified. Finally, according to a circular value-chain model, the system efficiency practices are specified and mapped to the components of the cyber-physical systems.	Supplement
ITU-T L.Suppl.55	Environmental efficiency and impacts on United Nations Sustainable Development Goals of data centres and cloud computing	This Supplement adopts a multi-impact and lifecycle perspective and addresses the following aspects of data centres (DCs) and cloud computing: • an overview of environmental and energy impacts of DCs and cloud computing taking a lifecycle approach; • an overview of socio-economic impacts; • a mapping of related sustainability and energy indicators and standards; • an overview of links to the 17 Sustainable Development Goals (SDGs).	Supplement

AI for Climate Solutions Standards

Number	Title	Scope	Category
ITU-T L.1326	Requirements and use cases of liquid cooling solutions and high energy efficiency solutions for 5G BBU in centralized-RAN mode	This Recommendation provides requirements for liquid cooling and high energy efficiency solutions for 5G BBU in centralized-RAN mode, including requirements of immersion and spray liquid cooling technology, key indicators of immersion and spray liquid, safety requirements of immersion and spray liquid cooling system, management procedure and an energy efficiency measurement method, and use cases of cooling solutions.	Product level
ITU-T L.1320	Energy efficiency metrics and measurement for power and cooling equipment for telecommunications and data centres	This Recommendation specifies principles and concepts of energy efficiency metrics and measurement methods for power feeding equipment and cooling equipment in telecommunications rooms and data centres. The methodologies defined in this Recommendation are applied at single equipment level. The efficiency of power conversion and cooling in the data centre or telecommunication facility is only partially attributed to the equipment. The architecture and organization of the space and equipment to deliver the power or cooling to the systems is as equal, if not a more significant factor in energy efficiency. Another general factor is the interoperability, management and response of these systems across the demand and operational range.	Product level
ITU-T L.1390	Energy saving technologies and best practices for 5G radio access network (RAN) equipment	This Recommendation identifies energy saving potentials, describes energy saving principles and technologies for 5G RAN and related equipment, and provides best practice recommendations on when and how these technologies should be used and controlled to reduce 5G RAN energy consumption.	Product level
ITU-T L.1480	Enabling the Net Zero transition: Assessing how the use of information and communication technology solutions impact greenhouse gas emissions of other sectors	This Recommendation provides guidance for assessing how the use of ICT solutions impacts GHG emissions of other sectors, using a robust and sound methodology. The guidance is agnostic to the outcome of the assessment, whether it be an addition or an avoidance of GHG emissions, and addresses positive and negative effects. Specifically, the methodology provides guidance on the assessment of the use of ICT solutions covering the net second order effect (i.e., the resulting second order effect after accounting for emissions due to the first order effects of the ICT solution), and the higher order effects. Moreover, the methodology also distinguishes between effects associated with actual reductions of GHG emissions and lesser increases in GHG emissions, as well as between immediate and mid-term/long-term effects.	Product level

(continued)

Number	Title	Scope	Category
ITU-T L.1305	Data centre infrastructure management system based on big data and artificial intelligence technology	This Recommendation describes specifications of a data centre infrastructure management (DCIM) system based on big data and artificial intelligence (AI) technology. The system will manage all infrastructure in the data centre at the same time through a comprehensive platform. The scope of this Recommendation includes: network infrastructure of management systems; standardization of data collection of the installed module; interconnection among various kinds of monitoring sub-systems; requirements for different functions in a DCIM.	Product level
ITU-T L.Suppl.48	Data centre energy saving: Application of artificial intelligence technology in improving energy efficiency of telecommunication room and data centre infrastructure	This Supplement identifies the new application of AI technology in improving energy efficiency of telecommunication room and data centre (DC) infrastructures. It will address how AI-based power management can provide the following capabilities: • Data collection in telecommunication room and DC infrastructure • Real-time analysis of the historical power consumption data and parameters of the target telecommunication room • The ability to train an intelligent model • Making reasonable adjustments dynamically to the air conditioning and temperature, so as to achieve energy saving in the telecommunication room and DC infrastructure	Supplement

(continued)

Number	Title	Scope	Category
ITU-T L.Suppl.53	Guidelines on the implementation of environmental efficiency criteria for artificial intelligence and other emerging technologies	This Supplement is intended to be used for policy-making and business decision-making by governments and enterprises at different scales in various industries. The Supplement achieves three goals. The first goal is to identify artificial intelligence (AI), AI-enabled, various forms of other emerging technologies and enablers from other emerging technologies taking consideration of regional differences, priorities and industries. By assessing mainstream as well as upcoming technologies in each particular region (with all ITU categorized regions included) most, if not all, of our stakeholders will be relevant to the conversation on technological impacts. The second goal is to explore the environmental impacts of possible examples of technologies identified through qualitative and quantitative factors of environmental indicators. The model to help achieve this goal is an adjusted lifecycle assessment of a product, which consists of three stages of implementing a technology. The three stages examined in order to connect environmental impacts to identified technology include: a) materials; b) use; and c) end-of-life. Although only a few examples of technologies are given in this Supplement, similar analysis and guidelines for implementing the environmental efficiency criteria of other technologies beyond this report can be conducted using the same framework as discussed in clauses 7 and 8 and the appendices. The third goal is to propose guidelines on implementing environmental efficiency criteria for AI and other emerging technologies at the macro and micro levels, including 1) data collection strategy prior to implementing guidelines in order to meet localized needs and ensure evidence-based approach for decision making; 2) proposed actions to be implemented at all three environmental stages identified for AI and other emerging technologies in the Supplement; 3) possible actions for other emerging technologies from a technological and environmental perspective; and 4) general guidelines for different stakeholders working in industries related to AI and other emerging technologies.	Supplement

Standards that Support AI as an Enabler for Climate Action

Number	Title	Scope	Category
ITU-T L.1300	Best practices for green data centres	This Recommendation specifies best practices aimed at developing green data centres. A green data centre can be defined as a repository for the storage, management, and dissemination of data in which the mechanical, lighting, electrical and computer systems are designed for maximum energy efficiency and minimum environmental impact. The construction and operation of a green data centre includes advanced technologies and strategies. The Recommendation provides a set of rules to be referred to when undertaking improvement of existing data centres, or when planning, designing or constructing new ones. The proposed best practices cover: • data centre utilization, • management and planning; • ICT equipment and services; • cooling; • data centre power equipment; • data centre building; • monitoring. The environmental impact of a data centre should be assessed in line with [ITU-T L.1400], [ITU-T L.1410] and [ITU-T L.1420].	Product level
ITU-T L.1305	Data centre infrastructure management system based on big data and artificial intelligence technology	This Recommendation describes specifications of a data centre infrastructure management (DCIM) system based on big data and artificial intelligence (AI) technology. The system will manage all infrastructure in the data centre at the same time through a comprehensive platform. The scope of this Recommendation includes: • network infrastructure of management systems; • standardization of data collection of the installed module; • interconnection among various kinds of monitoring sub-systems; • requirements for different functions in a DCIM.	Product level

(continued)

Number	Title	Scope	Category
ITU-T L.Suppl.41	Requirements on energy efficiency measurement models and the role of artificial intelligence and big data	Energy efficiency is a crucial issue for the sustainability of cities, today and in the future, especially due to the emerging appearance of smart cities (SC) and of cutting-edge technologies. Some emerging technologies, such as artificial intelligence (AI), big data, edge computing and cryptocurrency may not take sustainability into consideration during their development. These technologies often require a huge amount of energy, resulting in significant environmental footprints. It is important to understand how to enhance the energy efficiency of these technologies in the urban space, and to think of means to reduce the environmental footprint of these technologies. In this regard, the definition of an appropriate model that can evaluate the energy efficiency of these emerging technologies is crucial, especially within the urban space and under the lens of standardization requirements. More specifically, these technologies have to comply with the requirements of a city's energy system and with the planning for the city's sustainable future. Thus, this Supplement aims to investigate appropriate models to evaluate urban energy efficiency with a special focus on the emerging adoption of AI and big data.	Supplement
ITU-T L.Suppl.43	Smart energy saving of 5G base stations: Traffic forecasting and strategy optimization of 5G wireless network energy consumption based on artificial intelligence and other emerging technologies	This Supplement examines energy-saving technology for fifth generation (5G) base stations (BSs). Some energy-saving technologies developed since the fourth generation (4G) era are explained in detail, while artificial intelligence (AI) and big data technology are introduced in response to the requirement for an intelligent and self-adaptive energy-saving solution. This Supplement also elaborates intelligent technical guidance for smart energy saving of 5G BSs.	Supplement

(continued)

Number	Title	Scope	Category
ITU-T L.Suppl.48	Data centre energy saving: Application of artificial intelligence technology in improving energy efficiency of telecommunication room and data centre infrastructure	This Supplement identifies the new application of AI technology in improving energy efficiency of telecommunication room and data centre (DC) infrastructures. It will address how AI-based power management can provide the following capabilities: • Data collection in telecommunication room and DC infrastructure; • Real-time analysis of the historical power consumption data and parameters of the target telecommunication room; • The ability to train an intelligent model; • Making reasonable adjustments dynamically to the air conditioning and temperature, so as to achieve energy saving in the telecommunication room and DC infrastructure.	Supplement

(continued)

Number	Title	Scope	Category
ITU-T L.Suppl.53	Guidelines on the implementation of environmental efficiency criteria for artificial intelligence and other emerging technologies	The Supplement is intended to be used for policy-making and business decision-making by governments and enterprises at different scales in various industries. This Supplement achieves three goals. The first goal is to identify artificial intelligence (AI), AI-enabled, various forms of other emerging technologies and enablers from other emerging technologies taking consideration of regional differences, priorities and industries. By assessing mainstream as well as upcoming technologies in each particular region (with all ITU categorized regions included) most, if not all, of our stakeholders will be relevant to the conversation on technological impacts. The second goal is to explore the environmental impacts of possible examples of technologies identified through qualitative and quantitative factors of environmental indicators. The model to help achieve this goal is an adjusted lifecycle assessment of a product, which consists of three stages of implementing a technology. The three stages examined in order to connect environmental impacts to identified technology include a) materials; b) use; and c) end-of-life. Although only a few examples of technologies are given in this Supplement, similar analysis and guidelines for implementing the environmental efficiency criteria of other technologies beyond this report can be conducted using the same framework as discussed in clauses 7 and 8 and the appendices. The third goal is to propose guidelines on implementing environmental efficiency criteria for AI and other emerging technologies at the macro and micro levels, including 1) data collection strategy prior to implementing guidelines in order to meet localized needs and ensure evidence-based approach for decision making; 2) proposed actions to be implemented at all three environmental stages identified for AI and other emerging technologies in the Supplement; 3) possible actions for other emerging technologies from a technological and environmental perspective; and 4) general guidelines for different stakeholders working in industries related to AI and other emerging technologies.	Supplement

Ongoing Work that Supports AI and the Environment

Number	Title	Scope
ITU-T L.FCC	Energy consumption management and optimization platform Framework for cloud computing	This Recommendation will define a framework for energy consumption management platform for cloud computing, as well as providing reference for cloud computing service providers to carry out and implement the design planning, construction and maintenance of cloud computing energy consumption management and optimization platform.
ITU-T L.Env_DC	Guidelines on Multi-Dimensional Environmental Metrics and Management for Data Centres	This Recommendation will detail the data centre environmental metrics consisting of, for example, energy use, carbon emission, recycling, and water use. It will issue guidelines on how to use the evaluation index system for specific DC, as well as proposing metrics that should be focused on at different stages of data centre development and recommendations for environmental metrics management.
ITU-T L.MM_Computing_power	Computing power efficiency matrix and measurement methodology	This Recommendation will be focusing on definition, matrix, and measurement methodology of computing power efficiency for Data Centre.
ITU-T L.CFSP	Guidelines for the assessment of the carbon footprint of Software products	This Recommendation will introduce the Guidelines for the assessment of the carbon footprint of Software products, including: • Determine the boundary and scope of the carbon footprint of software products; • Software product data collection, processing and quality control; • Software product carbon footprint measurement methods, evaluation indicators and reporting formats.
ITU-T L.TR_MS_DS	Measurement methods for energy consumption of the Domain Name System (DNS) in distributed data centres	This report will focus on measurement methods for energy consumption of the Domain Name System (DNS) in distributed data centres. It will provide a reference for data centre operators, cloud service providers, Internet service providers, Platform as a Service provider and Software as a Service provider, and the methodology to capture and compute the energy consumption of DNS traffic.

(continued)

Number	Title	Scope
ITU-T L.IEDL	Energy saving strategy for deep learning computing	This Recommendation will specify the energy saving strategy and best practice for deep learning computing scenarios. This Recommendation will include these aspects: 1) The energy cost for deep learning computing scenarios. 2) The energy saving strategy and best practice for deep learning computing scenarios.
ITU-T L.TR_TA_GC	Testing and Assessment method of Green Computing Power	This Technical Report will propose an evaluation model for environmental aspects of computing power. It will provide a reference for computing power service providers to carry out and implement design planning, construction, implementation, testing and evaluation of computing power which considers: • computing power efficiency, • IT equipment hardware GHG emissions, • low-carbon supporting facility, and • clean-energy supply.
ITU-T L.DLEE	Deep Learning Computation Energy Efficiency Evaluation Framework and Metrics	This Recommendation will specify computation efficiency evaluation framework and metrics for deep learning computing scenarios. It will include the following aspects: 1) The conceptual framework for deep learning computation efficiency evaluation. 2) The metric for deep learning computation efficiency evaluation.
ITU-T L.S_AI	Recommendation for the design of environmentally Sustainable AI-based and XR-based Systems	This Recommendation will define: • Clear definition of Environmentally sustainable AI- and XR-based system • Design criteria for Environmentally sustainable AI- and XR-based system • Recommendations on design of Environmentally sustainable AI- and XR-based system.

(continued)

Number	Title	Scope
ITU-T L.ClimAI	Guidelines for Assessing the Impact of Artificial Intelligence on Greenhouse gas emissions	This Recommendation will specify guidelines for assessing the impact of artificial intelligence on greenhouse gas emissions. The scope includes: • Overview of the impacts of AI on greenhouse gas emissions; • Solutions and framework for evaluating the impact of AI on greenhouse gas emissions.
ITU-T L.liquid_DC	High Efficiency Liquid Cooling Solutions and Practices for Data Centres	This Recommendation will identify the current business changes in data centres and their impact on supporting infrastructure, proposes the comparison between air cooling and liquid cooling technologies and the current mainstream technology routes of liquid cooling and their working principles, including the technical architecture of cold plate liquid cooling, the facing problems and solutions in current stage, and the best practices, etc. Through the detailed analysis of the above content to achieve the following purposes: 1) To have a detailed understanding of the business changes in the data centre at the current stage and make predictions on the future business conditions, and to match the appropriate infrastructure solutions to meet the current and future development requirements of the data centre. 2) To analyse the current mainstream liquid cooling technology and making suggestions on the current application direction. 3) To analyse the current application of cold plate liquid cooling problems encountered and proposed solutions, while providing best practices.

ITU Focus Group on Environmental Efficiency for Artificial Intelligence and Other Emerging Technologies (FG-AI4EE) – Deliverables Published on AI and the Environment

Number	Title	Scope	Category
FG-AI4EE-D.WG2-04	Effective use cases on employing artificial intelligence for achieving sustainable development goals and their applications in smart sustainable cities	Smart sustainable cities (SSCs) are the de facto model for the future cities built on smartness and sustainability. The term "smartness" refers to that quality of contributing to sustainable development and resilience through soundly based decision-making and the adoption of a long- and short-term perspective. One major aspect of this smartness is the growing reliance on artificial intelligence (AI) to conduct social, economic, public, and personal activities. The term "sustainability" means that activities in such smart sustainable cities respect the sustainable development goals (SDGs) set by members of the United Nations in 2015. The purpose of this Technical Report is to present effective use cases of AI applications that contribute to the ambitions of SSCs and the SDGs as well.	Smart Sustainable Cities
FG-AI4EE D.WG1-10	Guidelines on the use of digital twins of cities and communities for better climate change mitigation solutions	This Technical Report provides guidelines on how to use the United Nations United for Smart Sustainable Cities (U4SSC) KPI system [ITU-T Y.4903] in a digital twin city or community, to identify high impact climate change mitigation solutions. This Technical Report includes a set of use cases showing examples of projects where emerging technologies, such as machine learning (ML), augmented reality (AR) and artificial intelligence (AI) have been or could be used to reduce the negative impact of climate change in cities and communities. It lists a set of online videos and testimonials to illustrate those examples.	Smart Sustainable Cities

(continued)

Number	Title	Scope	Category
FG-AI4EE D.WG1-06	Neutral navigational matrix for AI driven technologies for smart sustainable cities	This Technical Report contains a high-level impact matrix that aims to support policy-makers, city planning authorities, project managers, private sector companies, parliamentary or governmental bodies, lawyers, scientists, and any other relevant stakeholders, in developing and evaluating regulation and legislation concerning artificial intelligence (AI), and assessing the implication of different AI and blockchain solutions on the city's scale, to orient smart sustainable city planning. The objective of this matrix is to provide the necessary tools for relevant stakeholders to determine the most impactful AI and blockchain solutions, to improve the environmental performance of these technology solutions and prioritize solutions and design possibilities that are best aligned with the values of the United Nations Sustainable Development Goals and the United for Smart Sustainable Cities KPIs [U4SSC], and [FG-AI4EE D.WG1-04].	Smart Sustainable Cities
FG-AI4EE D.WG1-11	Best practices for graphical digital twins of smart cities	This example-based Technical Report details how emerging technology solutions can be used to address environmental issues in an urban environment. The data used is based on information gained from the United Nations ''United for smart sustainable cities" [b-U4SSC 2021] reports. It focuses on comparing results from different cities around the world and looking at the areas where cities gained low results. The report also attempts to answer the following questions: • What are the emerging technologies that could improve these results? • How should the data be structured to improve results?	Smart Sustainable Cities

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Number	Title	Scope	Category
FG-AI4EE-D.WG1-08	Driving AI-IoT design towards the UN sustainable development goals (SDGs)	This Technical Report is intended to raise awareness about the need for a comprehensive approach to AI-IoT product/service design capable of integrating and harmonizing environmental, social, and economic dimensions of sustainability. It highlights current barriers and future risks for the achievement of sustainability targets that stem from common single-path approaches. The document provides recommendations for future work on how best to embed all three sustainability requirements into the design process of AI-IoT services/products. Although this Technical Report focuses on the design of artificial intelligence (AI) and Internet of things (IoT) systems, our discussion applies to digital technologies more broadly. It aims to highlight: • Current barriers to a comprehensive approach to AI-IoT sustainability, the risks of pursuing single-path approaches, and the need for a multi-dimensional approach during the technical design of new solutions. • Elements that can facilitate the above, such as integration at design, including an outline of future work for recommendations.	AI and Sustainability
FG-AI4EE D.WG1-04	Key performance indicators for small and medium enterprises to assess the achievement of sustainable development goals	This ITU-T Technical Specification outlines the key performance indicators (KPIs) in the context of smart, sustainable small and medium enterprises (SMEs) used to assess the achievement of sustainable development goals (SDGs). Evaluating these indicators can help SMEs, and their stakeholders understand to what extent their economic activity is sustainable.	AI and Sustainability

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Number	Title	Scope	Category
FG-AI4EE-D.WG1-02	Solution scorecard for eco-friendly business processes and environmental behavioural influencers	This Technical Report provides recommendations and brief self-assessment solution scorecards for organizations to perform an impact assessment aimed at quantifying the environmental impact of the work they conduct. • The first section covers eco-friendly business processes, provides some brief examples, and offers a rating system for organizations to self-assess the positive and negative impacts they are creating, and in some cases offers recommendations on finding more environmentally friendly practices as substitutes for a business process/function. • The second section explores the environmental behavioural influencers and proposes a scoring/scorecard system for measuring the positive impact organizations have created (internally and/or externally) on individuals who have incorporated more eco-friendly behaviours and practices in their regular activities. It does not cover individual behaviours that are climate positive such as recycling, re-use of materials, and zero waste practices et al as these are well documented in numerous other sources. The focus is on broader behaviours that create climate champions.	AI and Sustainability
FG-AI4EE D.WG2-06	Assessing environmentally efficient data centre and cloud computing in the framework of the UN sustainable development goals	This Technical Report will adopt a multi-impact and lifecycle approach, and include the following aspects: • An assessment of environmental and energy impacts of data centre and cloud computing through a lifecycle approach. • A mapping of available sustainability and energy measurements of data centre and cloud computing. • An analysis of the links to the 17 SDGs with breakdown indicators being evaluated. • A policy gap analysis of policies that facilitate the development of environmentally efficient data centres and cloud in support of the achievement of the Paris agreement and the UN SDGs.	AI and Sustainability

(continued)

Number	Title	Scope	Category
FG-AI4EE D.WG3-02	Smart energy saving of 5G base stations: Based on AI and other emerging technologies to forecast and optimize the management of 5G wireless network energy consumption	This Technical Report focuses on energy-saving technology of base stations (BS). Some energy- saving technologies since the 4G era will be explained in detail while artificial intelligence (AI) and big data technology will be introduced in response to the requirement of an intelligent and self adaptive energy saving solution. Intelligent technical guidance for smart energy saving of 5G base stations will also be elaborated in this report.	Energy Efficiency and Management
FG-AI4EE D.WG2-03	Requirements on energy efficiency measurement models and the role of AI and big data	Energy efficiency is a crucial issue for the sustainability of cities, today and in the future, especially due to the emerging appearance of smart cities (SC) and of cutting-edge technologies. Some emerging technologies, such as artificial intelligence (AI), big data, edge computing and cryptocurrency may not take sustainability into consideration during their development. These technologies often require a huge amount of energy, resulting in significant environmental footprints. It is important to understand how to enhance the energy efficiency of these technologies in the urban space and to think of means to reduce the environmental footprint of these technologies (ITU, 2019a). In this regard, the definition of the appropriate model that can evaluate the energy efficiency of these emerging technologies is crucial, especially within the urban space and under the lens of their standardization requirements. More specifically, these technologies have to comply with the requirements of a city's energy system and with the planning for a city's sustainable future. Thus, this Technical Report aims to investigate the appropriate models to evaluate urban energy efficiency with a special focus on the emerging adoption of AI and big data.	Energy Efficiency and Management

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Number	Title	Scope	Category
FG-AI4EE D.WG2-05	Guidelines on energy efficient blockchain systems	Energy efficiency is a crucial issue for present-day and future city sustainability, especially due to the emerging appearance of smart cities (SC) and of cutting-edge technologies. Some emerging technologies, such as, for instance, blockchain and its role in cryptocurrency and contracting, may not take sustainability into consideration during their development. These technologies often require a huge amount of energy, leaving behind a significant environmental footprint. It is important to understand how to reduce the environmental impact of these technologies because this will contribute to the well-being of the market economy, as well as to the quality of life of citizens and the users of these technologies. In this regard, the definition of the blockchain energy requirements and of the means that can enhance blockchain energy efficiency would be useful. Thus, this work aims to define the blockchain energy efficiency model.	Energy Efficiency and Management
FG-AI4EE D.WG3-03	Data centre energy-saving: Application of AI technology in improving energy efficiency of telecom equipment rooms and Internet data centre infrastructure	This Technical Report identifies the new application of AI technology in improving energy efficiency of telecom equipment rooms and Internet data centre infrastructure. It will address how AI-based power management can achieve the following capabilities: • Data collections in telecom equipment rooms and IDC infrastructure. • Real-time analysis of the historical power consumption and parameters of the target equipment room. • The ability of training an intelligent model and • Making reasonable timely adjustments to the air-conditioning and temperature, so as to achieve energy-saving in the telecom equipment rooms and IDC infrastructure.	Energy Efficiency and Management

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Number	Title	Scope	Category
FG-AI4EE D.WG3-01	Guidelines on the implementation of ecofriendly criteria for AI and other emerging technologies	The Technical Report is intended to be used for policy-making and business decision-making by governments and enterprises at different scales in various industries. This report aims to achieve three goals. The first goal is to identify artificial intelligence (AI), AI-enabled and various forms of other emerging technologies and enablers from other emerging technologies taking due consideration of regional differences, priorities and industries. By assessing the mainstream, as well as upcoming technologies in each particular region (with all ITU categorized regions included), determining whether most, if not all, of our stakeholders would be relevant in the conversation on technological impacts. The second goal, as a deliverable for part of the Artificial Intelligence for Environmental Efficiency Group, is to explore environmental impacts of possible examples of technologies identified through qualitative and quantitative factors of environmental indicators. The model to help achieve this goal is an adjusted "lifecycle assessment of product" model, which consists of three stages of implementation of a technology. The three stages examined in order to connect environmental impacts to identified technology include a) materials; b) use; and c) end-of-life. Although only a few examples of technologies are given in this report, similar analysis and guidelines for implementing eco-friendly criteria of other technologies beyond this report can be conducted using the same framework presented in clauses 7, 8 and in the annexes. The third goal is to propose guidelines and recommendations on implementing eco-friendly criteria for AI and other emerging technologies at macro and micro levels, including 1) data collection strategy prior to implementing recommendations in order to meet localized needs and ensure evidence-based approach for decision making; 2) recommended actions to be implemented at all three environmental stages identified for AI and other emerging technologies in this report; 3) possible actions for other emerging technologies from a technological and environmental perspective; and 4) general recommendations for different stakeholders working in industries related to AI and other emerging technologies.	Environmental Efficiency in AI Processes

(continued)

Number	Title	Scope	Category
FG-AI4EE D.WG3-07	Guidelines on the environmental efficiency of machine learning processes in supply chain management	This guidance document is intended to support machine learning (ML) researchers and operators to measure and improve the environmental efficiency of ML, artificial intelligence (AI) and other emerging technologies used in supply chain management. The requirements, recommended processes, best practices and other considerations regarding the measurement and verification of environmental impact/efficiency contained in this document are developed based on inputs from leading academic experts and industry leaders. These requirements provide general guidelines applicable to the use of ML, AI and other emerging technologies in supply chain management. Other stakeholders may also use this guidance document to gain a new understanding of the environmental impacts of ML, AI and other emerging technologies used in supply chain management.	Environmental Efficiency in AI Processes
FG-AI4EE D.WG2-02	Computer processing, data management and energy perspective	This Technical Report presents a set of well-adopted energy efficiency practices for cyber-physical system classes and applications – enabled by artificial intelligence (AI), big data (BD), Internet of Things (IoT) and other innovative technologies. To do so, a set of relevant and significant use cases are first introduced. Second, system classes are identified. Finally, according to a circular value-chain model, system efficiency practices are specified and mapped to components of cyber-physical systems.	Environmental Efficiency in AI Processes
FG-AI4EE D.WG1-05	Reporting templates on artificial intelligence, augmented reality and machine learning	This Technical Report generates a set of standard reporting templates/dashboards to visualize data produced from technology solutions such as artificial intelligence (AI), augmented reality (AR) and machine learning (ML) that employ defined ecofriendly practices. This Report aims to display the results gained from FG-AI4EE deliverable D.WG1-04 in an instinctive way. The graphical interface will share a design language with FG-AI4EE deliverable D.WG1-09, whose results are used in FG-AI4EE deliverables D.WG1-10 and D.WG1-11.	Reporting and Methodology

(continued)

Number	Title	Scope	Category
FG-AI4EE-D.WG1-01A	Standardized glossary of terms	This Technical Report contains a dictionary of common terms and phrases used in the Focus Group's deliverables that is intended to help readers to have common definitions and frames of reference. To aid understanding of papers submitted within the Focus Group, a glossary of terms has been created to aid readability. Each definition covers the term itself, and any illustration, mathematical or otherwise to enable understanding of the term used. Where terms are already standardized within the industry, a reference will refer to the underlying defined term.	Reporting and Methodology
FG-AI4EE D.WG1-09	A method for intuitive human interaction with data model (ML and AI, etc.)	A review of the gaps between the needs and tools is performed, together with a case study of the benefits of 4D interactive visualisation of data models for environmentally friendly artificial intelligence (AI) and machine learning (ML).	Reporting and Methodology

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