ITU-T Focus Group Deliverable

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Focus Group on Environmental Efficiency for Artificial Intelligence and other Emerging Technologies

(FG-AI4EE)

FG-AI4EE D.WG1-05

Reporting templates on artificial intelligence, augmented reality and machine learning

Working Group 1 - Requirements of AI and other Emerging Technologies to Ensure Environmental Efficiency

ITU-T FG-AI4EE Deliverable

Reporting templates on artificial intelligence, augmented reality and machine learning

Summary

Technical Report FG-AI4EE D.WG1-05 focuses on how emerging technology solutions can be most impactful on environmental issues that cities face. The data used is based on information gained from the United Nations "United for Smart Sustainable Cities" reports [b-U4SSC]. The Internet of things (IoT) and smart cities gather a substantial amount of data in data lakes and present the insights generated by machine learning or artificial intelligence in custom proprietary dashboards or open application programming interfaces (APIs). It is a tedious task for stakeholders with low data literacy to capture so much information stemming from various data formats in a way that can inform their decisions and adapt their behaviours toward a more sustainable future. In light of the United Nations' Agenda 2030 and the European Commission's Fit-for-55 target, there is a critical need for a visualization tool which can visualize and compare, in a consistent manner, the sustainability of smart cities and using which, priorities can be identified and anchored at all decision-making levels with best practices being scaled-up and replicated in other cities. The purpose of this Report is thus to identify the emerging technologies and allow a prompt comparison between different cities and help identify low-hanging fruit and areas of high priority. For the sake of portability and reproducibility, attention is drawn to potential universal data formats.

Keywords

Emerging technologies, graphical digital twins, KPIs, replication, scalability, sustainability, U4SSC, visualization.

Note

This is an informative ITU-T publication. Mandatory provisions, such as those found in ITU-T Recommendations, are outside the scope of this publication. This publication should only be referenced bibliographically in ITU-T Recommendations.

Change Log

This document contains Version 1.0 of the ITU-T Technical Report on "*Reporting templates on artificial intelligence, augmented reality and machine learning*" approved at FG-AI4EE sixth meeting held in Ålesund, Norway, 1–2 December 2022.

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ITU-T FG-AI4EE Deliverable

Reporting templates on artificial intelligence, augmented reality and machine learning

1   Scope

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.

2   References

[ITU FG-AI4EE D.WG1-04]	ITU FG-AI4EE D.WG1-04 (2021), *Key performance indicators for small and medium enterprises to assess the achievement of sustainable development goals*. http://handle.itu.int/11.1002/pub/81a36bd6-en
[ITU FG-AI4EE D.WG1-09]	ITU FG-AI4EE D.WG1-09 (2021), *A method for intuitive human interaction with data model (ML and AI, etc.)*. http://handle.itu.int/11.1002/pub/81a36bd9-en
[ITU FG-AI4EE D.WG1-10]	ITU FG-AI4EE D.WG1-10 (2022), *Guidelines on the use of digital twin of cities and communities for better climate mitigation solutions*. http://handle.itu.int/11.1002/pub/81cf9006-en
[ITU FG-AI4EE D.WG1-11]	ITU FG-AI4EE D.WG1-11 (2021), *Best practices for graphical digital twins of smart cities*. http://handle.itu.int/11.1002/pub/81ac7747-en
[ITU FG-AI4EE D.WG2-02]	ITU FG-AI4EE D.WG2-02 (2021), *Computer processing, data management and energy perspective*. https://www.itu.int/pub/T-FG-AI4EE-2021-D.WG2.02

3   Definitions

3.1   Terms defined elsewhere

This Technical Reports uses the following terms defined elsewhere:

3.1.1   artificial intelligence (AI) [b-ITU-T F.749.13]: 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.

3.1.2   augmented reality [b-ITU-T J.301]: A type of mixed reality where graphical elements are integrated into the real world in order to enhance user experience and enrich information.

3.1.3   big data [b-ISO/IEC 20546]: Extensive datasets – primarily in the data characteristics of volume, variety, velocity and/or variability – that require a scalable technology for efficient storage, manipulation, management, and analysis.

3.1.4   bitcoin [b-ITU-T X.1400]: An example of a blockchain using proof of work.

3.1.5 **blockchain** [b-ITU-T F.751]: A type of distributed ledger that is composed of digitally recorded data arranged as a successively growing chain of blocks with each block cryptographically linked and hardened against tampering and revision.

3.1.6 **building automation** [b-ITU FG-AI4EE D.WG3-03]: The automatic centralized control of a building's HVAC (heating, ventilation and air conditioning), electrical, lighting, shading, access control, security systems, and other interrelated systems through a building management system (BMS) or building automation system (BAS).

3.1.7 **cloud computing** [b-ITU-T Y.3500]: Paradigm for enabling network access to a scalable and elastic pool of shareable physical or virtual resources with self-service provisioning and administration on-demand.

3.1.8 **cyberphysical systems** [b-NIST]: Smart systems that include engineered interacting networks of physical and computational components.

3.1.9 **data centre** [b-ITU-T X.1053]: A facility used to house computer systems and associated components, such as telecommunication and storage systems.

3.1.10 **deep learning** [b-ISO/IEC TR 29119-11]: Approach to creating rich hierarchical representations through the training of neural networks with one or more hidden layers.

3.1.11 **digital twin** [b-ISO/TR 24464]: Compound model composed of a physical asset, an avatar and an interface.

3.1.12 **distributed ledger** [b-ITU FG-AI4EE D.WG2-05]: A type of ledger that is shared, replicated and synchronized in a distributed and decentralized manner.

3.1.13 **electrical energy efficiency** [b-ITU-T L.1315]: The output of a device that is generated by a provided amount of power; the percentage of total energy input to a machine or equipment that is consumed in useful work and is not wasted as useless heat.

3.1.14 **energy carrier** [b-ISO/IEC 13273-1]: Substance or medium that can transport energy.

3.1.15 **energy consumption** [b-ISO/IEC 13273-1]: Quantity of energy applied.

3.1.16 **energy efficiency** [b-ISO/IEC 13273-1]: Ratio or other quantitative relationship between an output of performance, service, goods or energy, and an input of energy.

3.1.17 **energy efficiency improvement** [b-ISO/IEC 13273-1]: Increase in energy efficiency as a result of technological, design, behavioural or economic changes.

3.1.18 **energy efficiency indicator** [b-ISO/IEC 13273-1]: Value indicative of the energy efficiency.

3.1.19 **energy efficiency mechanism** [b-ISO/IEC 13273-1]: Means used to create incentives or a supportive framework for market actors to follow an energy efficiency improvement programme or to provide energy efficiency services.

3.1.20 **energy intensity** [b-ISO/IEC 13273-1]: Quotient describing the total energy consumption per unit of economic output.

3.1.21 **energy management system** [b-ISO/IEC 13273-1]: Set of interrelated or interacting elements to establish an energy policy and energy objectives, as well as the processes to achieve those objectives.

3.1.22 **energy performance** [b-ISO/IEC 13273-1]: Measurable results related to energy efficiency, energy use and energy consumption.

3.1.23 **energy policy** [b-ISO/IEC 13273-1]: Statement by the organization of its overall intentions and direction of an organization related to its energy performance, as formally expressed by its top management.

3.1.24 energy source [b-ISO/IEC 13273-1]: Material, natural resource or technical system from which energy can be extracted or recovered.

3.1.25 energy system [b-FG-AI4EE D.WG2-03]: A system that consists of all the components related to production, conversion, delivery, and use of energy.

3.1.26 energy system models [b-FG-AI4EE D.WG2-03]: Conceptual tools that depict the structure and support the calculation of the technological performance and decision making for design, operation and control.

3.1.27 extended reality [b-ITU FG-AI4EE D.WG3-01]: Combines all forms of real-virtual environments and human-machine interactions, including but not limited to augmented reality, mixed reality, and virtual reality.

3.1.28 ICT energy efficiency [b-ITU FG-AI4EE D.WG2-03]: The ratio of energy consumed by specific ICT systems to the output produced or service performed by these systems.

3.1.29 industry 4.0 [b-ITU FG-AI4EE D.WG3-01]: An industrial approach where one or more digital technologies are used throughout industrial processes in order to produce more and better.

3.1.30 infrastructure-as-a-service (IaaS) [FG-AI4EE D.WG2-02]: A platform supporting the resources needed by other layers. IaaS can be "programmed" by utilizing provisioning tools. Because of this programming interface, even if IaaS is often (but not only) made of "physical" resources, IaaS can be considered as a component.

3.1.31 Internet of things [b-ITU-T Y.2060]: A global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies.

3.1.32 machine learning [b-ITU-T Y.3172]: Processes that enable computational systems to understand data and gain knowledge from it without necessarily being explicitly programmed.

3.1.33 mixed reality [b-ISO/IEC 18038]: Merging of real and virtual worlds to generate new environments where physical and synthetic objects co-exist and interact.

3.1.34 natural language processing [b-ITU-T F.746.3]: A method that analyses text in natural languages through several processes such as part-of-speech recognition, syntactic analysis and semantic analysis.

3.1.35 platform-as-a-service (PaaS) [FG-AI4EE D.WG2-02]: PaaS provides infrastructure, storage, database, information and process as a service, along with well-defined APIs, and services for the management of the running applications, such as dashboards for monitoring and service composition.

3.1.36 power usage effectiveness (PUE) [b-ISO/IEC 30134-2]: Ratio of the data centre total energy consumption to information technology equipment energy consumption, calculated, measured or assessed across the same period.

3.1.37 public key cryptography [b-ITU FG-AI4EE D.WG2-05]: (also called asymmetric key) is a milestone in the development of modern cryptography, which mainly includes a public key and a private key.

3.1.38 quantum computing [b-ISO/TS 80004-1]: Use of quantum phenomena for computational purposes.

3.1.39 smart contract [b-ITU FG-AI4EE D.WG2-05]: A program written on a distributed ledger system which encodes the rules for specific types of distributed ledger system transactions in a way that can be validated, and triggered by specific conditions; Software program that is executed automatically and capable of carrying out the terms of the agreement between parties without the need for human intervention; Pieces of software that execute a specified action based on the state of the system or a transaction that occurs.

3.1.40 smart sustainable city [b-ITU-T Y.4900]: An innovative city that uses information and communications technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental, as well as cultural aspects.

3.1.41 stateless contract [b-ITU FG-AI4EE D.WG2-05]: A contract lacking specified states.

3.1.42 TIMES [b-ITU FG-AI4EE D.WG2-03]: Energy efficiency model based on a linear programming.

3.1.43 token [b-ITU FG-AI4EE D.WG2-05]: A digital representation of value on a shared distributed ledger that is owned and secured using cryptography to ensure its authenticity and prevent modification or tampering without the owner's consent.

3.1.44 virtual reality [b-ISO 9241-394]: Set of artificial conditions created by computer and dedicated electronic devices that simulate visual images and possibly other sensory information of a user's surrounding with which the user is allowed to interact.

4 Abbreviations and acronyms

This Technical Report uses the following abbreviations and acronyms:

API	Application Programming Interface
CFO	Chief Financial Officer
COO	Chief Operation Officer
CSO	Chief Sustainability Officer
ESG	Environmental, Social and Governance
GB	Gigabyte
GHG	Greenhouse Gas Emissions
HR	Human Resources
HVAC	Heating Ventilation Air Conditioning
ISO	International Organization for Standardization
IT	Information Technology
KPI	Key Performance Indicator
PUE	Power Usage Effectiveness
VOC	Volatile Organic Compound

5 Conventions

None.

6 Structure of the Technical Report

FG-AI4EE deliverables D.WG1-04, D.WG1-09, D.WG1-10, D.WG1-11 argue in favour of the use of graphical digital twins to display sustainability reports. The following sub-clauses propose a list of KPIs, together with a brief description, their target audience and comment on their contextual benefit. For all the KPIs in Table 1, the CSO of the company (or anyone taking on this role) is responsible for providing accurate and updated figures.

6.1 Example of analysis from FG-AI4EE Technical Report D.WG2-02 "Computer processing, data management and energy perspective"

Table 1 – Analysis FG-AI4EE Technical Report D.WG2-02

Name and unit	Description	Target audience	Comment
Power usage effectiveness (PUE) [-]	Data centre efficiency Aggregated on which method?	Management, Information Technology (IT), CFO	Pure metrics on how efficient the HVAC of data centres are, unconnected to the purpose or usability of the data and calculations produced.
Local energy mix [kg CO2e/kWh]	CO_2 equivalent in kg for each locally produced kWh of energy consumed by the company, without accounting for green certificates	CFO, ESG	"How green are the actual electrons?" Aggregated on regional area and relevant period. Often provided by energy authorities. Companies sell green certificates to finance building carbon neutral infrastructure.
Effective energy mix [kg CO2e/kWh]	CO_2 equivalent in kg for each locally produced kWh of energy consumed by the company, accounting for green certificates	CFO, ESG	"How green are the virtual electrons?" Companies buy green certificates to compensate for a positive carbon output.
Percentage of reused training Parameters [-]	(No. reused)/(Total No.)	CFO, Data scientists	Data scientists must be made aware of the environmental impact of retraining the algorithms Reusing trained parameters has the potential downside of the "double black box": algorithm+dataset. This hinders interpretability.
Percentage of open datasets used in training [-]	Size of open dataset [GB]/Total size of datasets [GB]	Academia	Using open data sets streamlines the reproducibility and simplifies the interpretability of results.

Table 1 – Analysis FG-AI4EE Technical Report D.WG2-02

Name and unit	Description	Target audience	Comment
Percentage of training datasets reviewed by ethical committee [-]	(No. reviewed)/(Total No.)	ESG, HR department	HR department must be made aware of potential biases and intended and unintended discrimination in the choice of the training data.
Percentage of open datasets published [-]	(No. of openly published datasets created by the company)/(No.of datasets created by the company)	Internal and external data scientists, academia, p	Transparency in data is a key element. Publishing data can be a smart and inexpensive University marketing tactic.

6.2   Example of analysis from the D.WG1-04 list of KPI-metrics

Table 2 – Analysis from D.WG1-04 List of KPI-metrics

Parameter/performance indicator/KPI	Description	Target audiences	Comment
Percentage of workers practising physical activity at least three hours a week (%)		Management, HR, employees, municipal administration	Stakeholders must be made aware of the mobility situation and the potential health improvements related to physical activity and active mobility. Huge effect on well-being, life quality, life balance can be combined with cleaner transportation.
Greenhouse gases tonnes CO_2-equivalents)	Scope 1, 2 and 3	Management, employees, customers, ESG, investors	Stakeholders need to be made aware of the company's footprint.
Noise level around facilities (dB)	Measured with sensors		Use AI/digital signal processing to identify sources, categorize patterns, mitigate the consequences and generate fines based on pollution periods.
Number/percentage of third-party environmentally labelled products used in production (no.).	Should be split into the type of labels	ESG, COO	Used as sales and investor

Table 2 – Analysis from D.WG1-04 List of KPI-metrics

Parameter/performance indicator/KPI	Description	Target audiences	Comment
Number of third-party certified suppliers (no.).	Should be split into type of certificates	ESG, COO	Used as sales and investor
Percentage of procurement originating from second-hand retailers (%)	Promote circular business Models	ESG, COO	Used as sales and investor
Percentage of electronic equipment procured by second-hand retailers (%)	Promote longer IT-equipment life	ESG, COO	Used as sales and investor
Percentage of third-party environmentally labelled products and certified suppliers of total procurement costs (%)	Must be split into a set of performance indicators/measurable parameters and combined in a formula	ESG, COO	Used as sales and investor
Amount of paper and cardboard used (kg)	Purchased paper?	ESG	Limit unreusable packing solutions with a box in a box or cargo transporting air
Total use of fuel (L)	Should be split into type of fuels	ESG, CFO	Lower fuel use is good for the 3-bottom line
Number of travels by flight in the local region countries, in continent, in the rest of the world (no)		ESG	Stressing the lesser environmental profile of e-Meetings
CO_2-emissions from flights (tonne CO_2)	Calculation model to be described	ESG	
Percentage of Employees using mobility with lower footprint	Use of public transport, walking, biking	ESG, HR	Stressing the benefits for the 3 bottom lines: cheaper, healthier and more environmentally friendly
Percentage of employees with home office or flexible work hours		ESG, HR, COO, CFO	Stressing the benefits for the 3-bottom line: cheaper (less traffic, lower office rents), work-life balance and more environmentally friendly
Number of parking places paid by the company per employee		ESG, HR, COO, CFO	Helping employees making environmentally choices
Energy use from different energy sources (%)	Should be split into renewable/non-renewable	COO, CFO, ESG	Stressing the importance of clean energy sources

Table 2 – Analysis from D.WG1-04 List of KPI-metrics

Parameter/performance indicator/KPI	Description	Target audiences	Comment
Energy use for different purposes (kWh)	Should be split by category: Computing, HVAC, production, other	COO, CFO, ESG	Visualizing where the energy is used can be illuminating
Heated area (m^2)		COO, CFO, ESG	Can be compared with employee density and heating related costs
Electricity consumption by category	HVAC, IT (on premise and cloud),	COO, CFO, ESG	Shows indirect and direct electricity usage
Demand Response Adoption (%)	Number of sites with demand response adoption	COO, CFO, ESG, IT	Optimize energy consumption when the prices are most convenient
Emissions of Greenhouse gases (tonnes CO_2-equivalents)	Scope 1, 2 and 3	COO, CFO, ESG, HR	Educating a broader audience on greenhouse gas emissions (GHG) starts with opening the eyes of employees and showing where GHG emissions stem from in their own company
Emissions of NO_X (tonnes)	Scope 1, 2 and 3	COO, CFO, ESG, HR	Educating a broader audience on NOx starts with opening the eyes of employees and showing where NOx emissions stem from in their own company
Emissions of SO_2 (tonnes)	Scope 1, 2 and 3	COO, CFO, ESG, HR	Educating a broader audience on SO2 starts with opening the eyes of employees and where SOx emissions stem from in their own company
Emissions of volatile organic compounds (VOCs) (tonnes)	Scope 1, 2 and 3	COO, CFO, ESG, HR	Educating a broader audience on VOCs starts with opening the eyes of employees and showing where the VOC emissions stem from in their own company
Emissions of particles/sot/dust (tonnes)	Scope 1, 2 and 3	COO, CFO, ESG, HR	Educating a broader audience on particulate matter starts with opening the eyes of employees and showing

Table 2 – Analysis from D.WG1-04 List of KPI-metrics

Parameter/performance indicator/KPI	Description	Target audiences	Comment
			where the particulate matter emissions stem from in their own company
Total volume of fresh water consumed	Increase water-use efficiency for all	COO, CFO, ESG, HR	Educating a broader audience on water consumption starts with opening the eyes of employees and showing where the water consumption stems from in their own company
Total volume of wastewater (m^3)		COO, CFO, ESG, HR	Educating a broader audience on wastewater production starts with opening the eyes of employees and showing where the wastewater production stems from in their own company
Pollution to open water bodies by organic matters, suspended solids, oil products, etc.	Should be specified by type	COO, ESG, HR	Reputational risk mitigation (and removal)
Waste in different fractions (kg)	Should be split into waste categories (paper, plastics, etc), to be recycled or incinerated, etc, see below	COO, ESG, HR	Reputational risk mitigation (and removal)
Electric waste	Kg	COO, ESG, HR	Raise awareness of electric waste and a source of revenue
Paper and cardboard (tonnes/currency)	Measure the proportion of paper and cardboard in procurement. This also includes packaging		Use AI-powered sorting robots or smart dustbins to sort waste, use it as a bottom line for billing and reporting from waste collection company. Connect billing to environmental reporting. Certify origin and destination via smart contracts (distributed ledger technology). Use AR to visualize the flow of materials, their

Table 2 – Analysis from D.WG1-04 List of KPI-metrics

Parameter/performance indicator/KPI	Description	Target audiences	Comment
			destination and sensibilize employees and procurement on the topic and use it as a basis to compare performance with national level or previous years.
Glass (tonnes)			Use AI-powered sorting robots or smart dustbins to sort waste, use it as a bottom line for billing and reporting from waste collection company. Connect billing to environmental reporting. Certify origin and destination via smart contracts (distributed ledger technology). Use AR to visualize the flow of materials, their destination and sensibilize employees and procurement on the topic and use it as a basis to compare performance with national level or previous years.
Plastics (tonnes)	Open-source 3D printing applied at community level can logically shift the amounts from tonnes to kg.		Use AI-powered sorting robots or smart dust bins to sort waste and use it as a bottom line for billing and reporting from the waste collection company. Connect billing to environmental reporting. Certify origin and destination via smart contracts (distributed ledger technology). Use AR to visualize the flow of materials, their destination and sensibilize employees and procurement on the

Table 2 – Analysis from D.WG1-04 List of KPI-metrics

Parameter/performance indicator/KPI	Description	Target audiences	Comment
			topic and use it to compare performance with national level or previous years. Use open-source 3D printing and recycling for small-scale manufacturing in support of sustainable self-directed development.[1] This coupled distributed recycling and manufacturing process reduces embodied energy by half while substantially reducing the cost of consumer products, so it has an economic incentive. 3D printing upcycles plastic waste into a filament through a recyclebot (open-source waste plastic extruder), to be further upcycled into valuable consumer products [b-Zhong]. Open tools also reduce maintenance costs, i.e., if it breaks, a part can be repaired or built locally from the design flies [b-Novak].
Metals (tonnes)			Use AI-powered sorting robots or smart dust bins to sort waste and use it as a bottom line for billing and reporting from the waste collection company. Connect billing to environmental reporting. Certify origin and destination via smart contracts (distributed ledger technology).

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[1] https://reprap.org/wiki/Recyclebot

Table 2 – Analysis from D.WG1-04 List of KPI-metrics

Parameter/performance indicator/KPI	Description	Target audiences	Comment
			Use AR to visualize the flow of materials, their destination and sensibilize employees and procurement on the topic and use it to compare performance with national level or previous years. Use open-source 3D printing and recycling for small-scale manufacturing to support sustainable self-directed development.[2] This coupled distributed recycling and manufacturing process reduces embodied energy by half while reducing the cost of consumer products substantially, so it has an economic incentive. 3D printing upcycles plastic waste into a filament through a recyclebot (open-source waste plastic extruder), to be further upcycled into valuable consumer products [b-Zhong]. Open tools also reduce maintenance costs, i.e., If it breaks, a part can be repaired or built locally from the design flies [b-Novak].
Hazardous waste (tonnes)			Connect billing to environmental reporting. Certify origin and destination via smart contracts (distributed ledger technology). Use AR to visualize the flow of materials, their destination and

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2   https://reprap.org/wiki/Recyclebot

Table 2 – Analysis from D.WG1-04 List of KPI-metrics

Parameter/performance indicator/KPI	Description	Target audiences	Comment
			sensibilize employees and procurement on the topic and use it as a basis to compare performance with national level or previous years
Production waste sent to landfill (tonnes)			Connect billing to environmental reporting. Certify origin and destination via smart contracts (distributed ledger technology). Use AR to visualize the flow of materials, their destination and sensibilize employees and procurement on the topic and use it as the basis to compare performance with national level or previous years.
Waste sent to recycling (% of total)			Automatically connect to waster collecting company. Use AI to incentivize eco-friendly behaviour. Visualize industry average, own current and past performance.
Waste sent to incineration (% of total)			Automatically connect to waster collecting company. Use AI to incentivize eco-friendly behaviour. Visualize industry average, own current and past performance.

7   State of the art in environmental reporting

This section of the report should present a short overview the state of the art in the domain environmental reporting based on International Organization for Standardization (ISO) standards, and provide an analysis of possible improvements to reach wider audiences.

8 Using graphical digital twins for environmental reporting

This section of the report should present a short overview of the state of the art in the domain of artificial intelligence and machine learning for smart cities and earth observation and conclude with a list of unsolved challenges relative to stakeholders' involvement in the behaviour change and decision-making processes. This section should refer to [ITU FG-AI4EE D.WG1-09] and [ITU FG-AI4EE D.WG1-11].

Bibliography

[b-ITU-T F.746.3]   Recommendation ITU-T F.746.3 (2015), *Intelligent question answering service framework*.

[b-ITU-T F.749.13]   Recommendation ITU-T F.749.13 (2021), *Framework and requirements for civilian unmanned aerial vehicle flight control using artificial intelligence*.

[b-ITU-T F.751]   Recommendation ITU-T F.751 (1997), *Transmission characteristics and performance requirements of radio-relay systems for SDH-based networks*.

[b-ITU-T J.301]   Recommendation ITU-T J.301 (2014), *Requirements for augmented reality smart television systems*.

[b-ITU-T L.1315]   Recommendation ITU-T L.1315 (2017), *Standardization terms and trends in energy efficiency*.

[b-ITU-T X.1053]   Recommendation ITU-T X.1053 (1053), *Code of practice for information security controls based on ITU-T X.1051 for small and medium-sized telecommunication organizations*.

[b-ITU-T X.1400]   Recommendation ITU-T X.1400 (2020), *Terms and definitions for distributed ledger technology*.

[b-ITU-T Y.4000]   Recommendation ITU-T Y.4000/Y.2060 (2012), *Overview of the Internet of things*.

[b-ITU-T Y.3172]   Recommendation ITU-T Y.3172 (2019), *Architectural framework for machine learning in future networks including IMT-2020*.

[b-ITU-T Y.3500]   Recommendation ITU-T Y.3500 (2014), *Information technology – Cloud computing – Overview and vocabulary*.

[b-ITU-T Y.4900]   Recommendation ITU-T Y.4900/L.1600 (2016), *Overview of key performance indicators in smart sustainable cities*.

[b-NIST]   NIST SP 1500-201 (2017), *Framework for Cyber-Physical Systems: Volume 1, Overview*, https://dx.doi.org/10.6028/NIST.SP.1500-201

[b-ITU FG-AI4EE D.WG2-03]   ITU FG-AI4EE D.WG2-03 (2021), *Requirements on energy efficiency measurement models and the role of AI and big data*.

[b-ITU FG-AI4EE D.WG2-05]   ITU FG-AI4EE D.WG2-05 (2021), *Guidelines on energy efficient blockchain systems*.

[b-ITU FG-AI4EE D.WG3-01]   ITU FG-AI4EE D.WG3-01 (2021), *Guidelines on the implementation of eco-friendly criteria for AI and other emerging technologies*.

[b-ITU FG-AI4EE D.WG3-03]   ITU FG-AI4EE D.WG3-03 (2021), *Data centre energy-saving: Application of AI technology in improving energy efficiency of telecom equipment rooms and internet data centre infrastructure*.

[b-IEEE Software Defined Networks]   Home – IEEE Software Defined Networks

[b-ISO 9241-394]	ISO 9241-394:2020, *Ergonomics of human-system interaction – Part 394: Ergonomic requirements for reducing undesirable biomedical effects of visually induced motion sickness during watching electronic images.*
[b-ISO/IEC 13273-1]	ISO/IEC 13273-1:2015, *Energy efficiency and renewable energy sources – Common international terminology – Part 1: Energy efficiency.*
[b-ISO/IEC 18038]	ISO/IEC 18038:2020, *Information technology – Computer graphics, image processing and environmental representation – Sensor representation in mixed and augmented reality.*
[b-ISO/IEC 20546]	ISO/IEC 20546:2019, *Information technology – Big data – Overview and vocabulary.*
[b-ISO/IEC 30134-2]	ISO/IEC 30134-2:2016, *Information technology – Data centres – Key performance indicators – Part 2: Power usage effectiveness (PUE).*
[b-ISO/IEC AWI TS 29119-11]	ISO/IEC AWI TS 29119-11 (in preparation), *Information technology – Artificial intelligence – Testing for AI systems – Part 11.*
[b-ISO/IEC TR 30164]	ISO/IEC TR 30164:2020, *Internet of things (IoT) – Edge computing.*
[b-ISO/TR 24464]	ISO/TR 24464:2020, *Automation systems and integration – Industrial data – Visualization elements of digital twins.*
[b-ISO/TS 80004-1]	ISO/TS 80004-1:2015, *Nanotechnologies – Vocabulary – Part 1: Core terms.*
[b-Novak]	Novak, A. (2020), *Open Tools Create New Pathways to the Circular Economy*. https://www.wilsoncenter.org/blog-post/open-tools-create-new-pathways-circular-economy
[b-U4SSC]	United for Smart Sustainable Cities (2022), *City Snapshot.* https://u4ssc.itu.int/city-snapshot/
[b-Zhong]	Zhong, S., and Pearce, J. M. (2018), *Tightening the loop on the circular economy: Coupled distributed recycling and manufacturing with recyclebot and RepRap 3-D printing*, Resources, Conservation and Recycling, Vol. 128, pp. 48-58.

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