ISO/IEC TR 20226:2025-07 (E)

Information technology - Artificial intelligence - Environmental sustainability aspects of AI systems

Contents

Page

Foreword vi

Introduction vii

1 Scope 1

2 Normative references 1

3 Terms and definitions 1

4 Symbols and abbreviated terms 4

5 Purpose 5
5.1 General 5
5.2 The London Declaration 6
5.3 Existing International Standards 6
5.4 Environmental sustainability in the European Artificial Intelligence Act 6
5.5 Enacted climate change legislation and market response 6
5.6 Access to affordable, reliable, sustainable and modern energy 7

6 Environmental sustainability 7
6.1 General 7
6.2 Energy consumption 7
6.2.1 General 7
6.2.2 Types and sources of energy 8
6.2.3 Physical renewable energy supply, Power Purchasing Agreements and offsets 8
6.3 Geographic considerations 9
6.3.1 General 9
6.3.2 Location 9
6.3.3 Distribution of energy sources 9
6.3.4 Freight transportation of energy sources 9
6.3.5 Handling and storage of energy sources 10
6.4 Water use 10
6.5 Cooling 11
6.5.1 General 11
6.5.2 Types of cooling 11
6.5.3 Post cooling use 11
6.6 Carbon footprint 11
6.6.1 General 11
6.6.2 Applicable use of measurements and carbon accounting methods 12
6.6.3 Estimation versus measurement 13
6.6.4 Carbon leakage 13
6.7 Consumption patterns and rebound effects 13
6.8 Waste 13
6.8.1 General 13
6.8.2 Types of waste 13
6.8.3 E-waste 14

7 Perspectives of environmental sustainability of AI systems 14
7.1 General 14
7.2 AI system ecosystem 15

7.3 AI system life cycle 16
7.4 AI system supply chain 16
7.5 Other perspectives 16

8 AI system ecosystem perspective 17
8.1 General 17
8.2 AI system 17
8.3 AI application 18
8.4 Machine learning 18
8.5 AI engineering 18

8.6 Big data and data sources 19
8.7 Cloud and edge computing 19
8.8 Resource pools 19

9 AI system life cycle perspective 20
9.1 General 20
9.1.1 AI system life cycle in ISO/IEC 5338 20
9.1.2 Life cycle assessment in ISO 14040 and ISO 14044 21
9.2 Inception 22
9.3 Design and development 22
9.4 Verification and validation 23
9.5 Deployment 24
9.6 Operation and monitoring 24
9.7 Continuous validation 25
9.8 Re-evaluation 25
9.9 Retirement 25

10 AI system supply chain approach to determine environmental sustainability aspects 26
10.1 General 26
10.2 Elements 26
10.3 Mines 26
10.4 Smelters and refiners 27
10.5 Component manufacturers 27
10.6 Assemblers 27
10.7 Distributors 27
10.8 Domestic infrastructure 28
10.9 Internet infrastructure 28
10.10 AI Training 28
10.11 Data preparation, labelling and dataset size 28
10.12 Device abandonment 29
10.13 Collection of abandoned devices 31
10.14 Shipping of abandoned devices 31
10.15 Recovering of abandoned devices 32
10.16 Disposing of abandoned devices 32

11 Measuring the environmental sustainability aspects of AI systems 33
11.1 General 33
11.2 AI system ecosystem measurements 33
11.2.1 General 33
11.2.2 Energy consumption 33
11.2.3 CPU energy 33
11.2.4 GPU energy 33
11.2.5 Accelerated processing unit energy 33
11.2.6 Energy efficiency 34
11.2.7 Power usage effectiveness 34
11.2.8 Renewable energy factor 34
11.2.9 Water usage effectiveness 34
11.2.10 Carbon usage effectiveness 34
11.2.11 Energy efficiency improvement 34
11.2.12 Carbon efficiency 35
11.3 AI system life cycle measurements 35

11.3.1 General 35
11.3.2 Energy-Precision Ratio (M) 35
11.4 AI system supply chain measurements 35
11.4.1 General 35
11.4.2 Raw material extraction method 36
11.4.3 Transportation of materials 36
11.4.4 Material hazard and environmental leaching risk 36
11.4.5 Material sustainability 36
11.4.6 Material processing 36

11.4.7 Transportation emissions 37
11.4.8 Manufacturing and product emissions 37
11.4.9 Water use 37
11.4.10 Natural gas 37
11.4.11 Power 38
11.4.12 Light pollution 38
11.4.13 Electrical, signal or radio wave pollution 38
11.4.14 Physical ecosystem disruption 38
11.4.15 Community 38
11.5 Other measurements 38
11.5.1 General 38
11.5.2 Carbon intensity of a machine learning model 39
11.5.3 Software Carbon Intensity 39
11.5.4 Operational carbon emissions 40
11.5.5 Embodied carbon emissions 40

12 Approaches to reducing AI systems' negative environmental impacts 41
12.1 General 41
12.2 Ecosystem approaches 41
12.2.1 General 41
12.2.2 Geographic location 41
12.2.3 Carbon aware scheduling 41
12.2.4 Carbon aware pausing 41
12.2.5 Generative AI 42
12.2.6 Synthetic data 42
12.2.7 Adapting a foundation 42
12.2.8 Transfer learning 42
12.2.9 Use of structured data versus brute force 42
12.2.10 Utilising local hardware and specialised circuits 42
12.2.11 Augmenting cloud usage data 42
12.3 Life cycle approaches 43
12.3.1 General 43
12.3.2 Carbon-Aware Core SDK 43
12.3.3 Computationally efficient algorithms 43
12.3.4 Using pretrained models 43
12.3.5 Automated ML 43
12.3.6 Federated learning methods 44
12.3.7 Customized processors 44
12.3.8 Energy efficient reinforcement learning practises 44
12.3.9 Using public APIs 44
12.4 Supply chain approaches 44
12.4.1 General 44
12.4.2 Certification of hardware and data centres 44
12.4.3 Using recycled rare earth elements in AI specific hardware 44
12.4.4 Applying circular economy concepts and principles 45
12.4.5 Business-improvement methodologies 45

Annex A This document's clauses mapped to the UN Sustainability Development Goals 46

Bibliography 49