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FOLLOWING THE PRECAUTIONARY PRINCIPLE: OPPORTUNITIES FOR STRENGTHENING ENVIRONMENTAL REGULATION IN THE EU AI ACT

Abstract: The rapid development of artificial intelligence (AI) has generated significant environmental challenges, including massive energy and water consumption, substantial carbon emissions, increasing electronic waste, and the ecological burden of rare earth mineral extraction. This study examines the extent to which the precautionary principle is applied within the EU Artificial Intelligence Act (Regulation (EU) 2024/1689) (AIA) and explores opportunities to strengthen its environmental dimension.

The EU AIA represents a landmark regulatory framework aimed at addressing the risks posed by AI. While Article 1 explicitly includes environmental protection among the values to be safeguarded, the concrete environmental provisions remain relatively weak and primarily procedural. Key articles — notably Article 40 (harmonized standards for energy efficiency and resource use), Article 95 (codes of conduct), and Annex XI (energy consumption reporting for general-purpose AI models) — rely mainly on voluntary measures and transparency obligations rather than binding requirements.

A central argument of the paper is that the precautionary principle, a cornerstone of EU environmental law (TFEU art. 191(2)), offers a robust legal basis for addressing scientific uncertainties surrounding the environmental impacts of AI systems. The current Act falls short of

requiring mandatory Environmental Impact Assessments (EIA) or lifecycle evaluations for high-risk and high-energy AI models.

The study identifies substantial opportunities to strengthen the environmental regulation of AI during the forthcoming review period. Proposed measures include introducing obligatory sustainability impact assessments for large-scale models, or establishing environmental threshold values, and integrating sustainability risks more effectively into the risk-based approach of the Act.

By applying a legal-dogmatic and policy-oriented analysis, this paper highlights the "green gaps" in the EU AI Act and provides recommendations for advancing a more sustainable and precautionary regulatory framework for artificial intelligence in Europe.

Keywords: *Precautionary Principle, EU AI Act, Environmental Regulation, Sustainable AI, AI Environmental Governance*

INTRODUCTION

The European Union Artificial Intelligence Regulation (Regulation (EU) 2024/1689) (AIA) entered into force on 1 August 2024 and is being applied progressively. It is the world's first comprehensive, horizontal AI regulation, based on a risk-based approach: it prohibits cer

tain practices, imposes strict obligations on high-risk systems, and introduces transparency rules for limited-risk systems.

The creation of the Regulation is framed by the EU's twin digital and green transitions. As part of the European Green Deal and the digital strategy, the AI Act aims to ensure that AI contributes to sustainable development while minimising risks to health, safety, fundamental rights, and the environment. Recital 4 AIA states that AI can provide socially and environmentally beneficial outcomes, including in energy, resource and energy efficiency, environmental monitoring, and the conservation and restoration of biodiversity, and that it can optimise operations and resource allocation. At the same time, it acknowledges the negative environmental impacts of AI, such as high energy consumption, water use, and electronic wast.

In the international regulatory landscape, the EU AI Act is considered ambitious. The United States follows a sectoral, largely voluntary approach (Ebert et al. 2026. p. 6.) with fewer mandatory environmental requirements.

In China, state-directed, security-focused regulation prevails, treating green AI as a strategic tool, though public, model-level environmental transparency remains lower (Roachell, 2026). Canada focuses primarily on government automated decision-making (Treasury Board of Canada Secretariat, 2020). UNESCO (2021) and the OECD AI Principles (OECD, 2019/2024, Principle 1.1) include ethical and sustainability principles but are non-binding. The EU AI Act thus seeks to assume a global leadership role, although critics argue that the environmental dimension was weakened compared with the European Parliament's version, as stronger obligations disappeared during the trilogue negotiations (more about it Laranjeira de Pereira, 2024).

Despite the significant environmental costs of training and operating AI systems (Luccioni et al., 2024, pp. 85–99), the European legislator has chosen a transparency regime instead of a responsibility-based approach (Wachter, 2024, p. 714).

The AIA classifies AI systems and attaches different requirements to a risk-based approach (AIA Recital 26; Arts. 5–6 and 50; Chapter V). Systems presenting unacceptable risks are prohibited (Art. 5). A wide range of high-risk AI systems that may adversely affect health, safety or fundamental rights may be placed on the market only if they meet the requirements and obligations of the Act (Arts. 6 and 8–27; Annexes I and III). Systems posing limited risks because of their lack of transparency are subject to information and transparency duties (Art. 50). Systems presenting only minimal risk are not subject to further obligations under the Act. The regulation also lays down specific rules for general-purpose AI (GPAI) models (Arts. 53–54) and more stringent duties for GPAI models with high-impact capabilities that may pose systemic risk and have a significant impact on the internal market (Arts. 51–52 and 55; Annex XIII). While the risk-based classification is itself an example of precautionary regulation, this study investigates those provisions of the AI Act that specifically address environmental concerns in accordance with the precautionary principle.

The environmental burden of AI is increasingly driven by deployment, not only training: inference can dominate the lifecycle of widely used systems, yet it remains poorly quantified. Multi-purpose generative architectures are orders of magnitude more energy- and carbon-intensive than task-specific models for many tasks, even when model size is held constant. Public reporting of architecture, energy use, and emissions is limited, which makes systematic comparison and sector-level estimates difficult. The utility of general-purpose systems should therefore be weighed more intentionally against these costs; better measurement can

inform practitioners' deployment choices and support policy-makers working to estimate and regulate the environmental impacts of AI. This is "(…) caution that their utility should be more intentionally weighed against increased costs in terms of energy and emissions." (Luccioni et al., 2024, p. 85.)

Materials and Methods

This study employs a qualitative doctrinal legal research methodology combined with a normative policy analysis to examine the integration of the precautionary principle into the environmental dimensions of the EU Artificial Intelligence Act (AIA) The primary materials consist of the official text of the AI Act, including its recitals, articles, and annexes, as published in the Official Journal of the European Union. Supplementary sources include relevant EU treaties (notably Articles 191(2) TFEU), preparatory documents from the European Commission, European Parliament, and Council (trilogue negotiations), as well as CJEU case law on the precautionary principle.

Secondary literature encompasses academic articles, policy reports, and expert commentaries on AI regulation, environmental law, and sustainability. International instruments, such as the Rio Declaration (United Nations, 1992, Principle 15), OECD guideline, were also consulted for comparative context. The analysis follows a systematic, article-by-article approach, where identified and evaluated against the core elements of the precautionary principle. A normative lens was applied to assess the extent to which these provisions operationalise precautionary logic in the environmental domain, highlighting both strengths (e.g., transparency and risk-based classification) and weaknesses (e.g., the voluntary nature of sustainability measures and the absence of mandatory lifecycle assessments).

The Precautionary Principle

The precautionary principle originated in international environmental law and was clearly articulated in the 1970s. The precautionary principle as in German: *Vorsorgeprinzip,* first emerged in German environmental law in the early 1970s. It later gained broader international recognition and a widely cited formulation in the 1992 Rio Declaration on Environment and Development (Principle 15), adopted at the United Nations Conference on Environment and Development (Earth Summit) in Rio de Janeiro. It urges states to apply broad precautions to protect the environment, stating that where there is a risk of significant or irreversible damage, the lack of full

scientific certainty should not delay effective preventive measures. The principle appears in major international agreements, including the Rio Declaration, the Maastricht Treaty, and the Treaty of Amsterdam. At its core is the idea that, even when there is scientific uncertainty or differing views about the severity of potential harms — as in the case of climate change — policymakers should consider the widest range of scientific evidence and take precautionary action to address possible unforeseen consequences.

However, the principle carries universal values and obligations, even beyond the topic of climate change: if the development of our world or technology threatens irreversible damage, it is in the best interest of the future generation that responsible decision-makers take effective precautionary measures.

The precautionary principle is now one of the main pillars of the European Union's environmental policy. Article 191(2) of the Treaty on the Functioning of the European Union (TFEU) states that Union policy on the environment shall aim at a high level of protection, while taking into account the diversity of situations in the various regions of the Union. This policy is based on the precautionary and preventive principles, the principle that environmental damage should be rectified primarily at source, and the polluter pays principle. As a result, the EU institutions and the Member States are required to apply the precautionary principle in the field of environmental policy. The case law of the Court of Justice of the European Union has been central to the further development of that principle in EU law. Early guidance was given in Case 174/82 Sandoz [1983] ECR 2445. The Court then applied it to emergency health measures in the BSE litigation, in particular Case C-157/96 National Farmers' Union and Others [1998] ECR I-2211 and Case C-180/96 United Kingdom v Commission [1998] ECR I-2265. The conditions for its application were set out in greater detail by the Court of First Instance in Case T-13/99 Pfizer Animal Health SA v Council [2002] ECR II-3305.

The application of the precautionary principle has come a long way since the Stockholm Conference (1972) and has gained particular significance in the regulation of areas where technology is advancing rapidly. This is particularly evident in fields such as the pharmaceutical industry and the legal regulation of genetic modification (Tahyné, 2025, 142.) However, AI differs fundamentally. Its "black box" nature—where even developers may not fully understand internal processes—combined with its reliance on vast, dynamic datasets and probabilistic outputs, makes it difficult to predict specific harms ex ante. Unlike physical products, AI's risks often emerge from its interaction with human behavior and societal systems, complicating

traditional safety assessments. (for a fuller discussion, see Howell, 2024, p 2., 3.)

Environmental Implications of the AI Act

1. Resource efficiency standards and harmonised standards (Article 40)

Article 40 empowers the European Commission to develop harmonised standards (See further Leyden, A., 2026, p 270.) in cooperation with standardisation organisations (e.g., CEN, CENELEC), to improve the resource performance of AI systems and general-purpose AI models (GPAI). The focus is on energy efficiency and the reduction of energy and other resource consumption throughout the entire lifecycle (training, inference, deployment). Primarily applies to high-risk AI systems and GPAI models. The standards are voluntary, but compliance creates a presumption of conformity with the Regulation's requirements. The Commission may request the development of standards covering reporting, documentation, and measurement. (Article 40(2))

The main challenges can be summarised as follows. The development of standards is a slow process. Furthermore, the framework does not establish mandatory minimum thresholds (e.g., specific CO_2 emission quotas). Conducting comprehensive life-cycle assessments (LCA) is highly complex, as it involves measuring the full value chain, including hardware manufacturing, data centre operations, and electronic waste. In addition, compliance can impose significant costs on small and medium-sized enterprises (SMEs). Critics argue that these provisions function more as incentives than as effective enforcement mechanisms and do not guarantee actual environmental reductions. (See further Laranjeira de Pereira, 2024)

In issuing standardisation requests, the Commission must also ensure coherence and clarity in the resulting standards to guarantee output legitimacy. Article 40(2) requires the Commission to specify that the standards must be clear and consistent, including alignment with standards developed under other Union harmonisation laws for related sectors. The objective is to prevent conflicting norms, ensuring that AI systems embedded in other products can comply with both the AI Act standards and existing sectoral standards without contradiction. Moreover, Article 40(2) obliges the Commission to request the European standardisation organisations (ESOs) to demonstrate their 'best efforts' in achieving these objectives (clarity and consistency), in accordance with Article 24 of Regulation (EU) No 1025/2012, which requires the ESOs to report on the implementation of the Commission's requests. These procedural safeguards address longstanding criticisms that harmonised standards sometimes

diverge from legal requirements or leave regulatory gaps. (see further about Leyden, A., 2025, p. 273.)

2. Energy consumption documentation for GPAI models (Annex XI and related articles)

Providers of GPAI models (e.g., foundation models such as those similar to OpenAI's) must prepare and maintain technical documentation that includes the known or estimated energy consumption of the model (Annex XI. 2.e). The AI Office may request this information at any time. These obligations apply to all large general-purpose AI models. Transitional arrangements exist for models placed on the market before 2 August 2025 (compliance required by 2 August 2027).

Where the actual energy consumption is unknown, providers may base the estimate on computational resources used. (Annex XI. 2.). Only estimates are required — there is no obligation for mandatory accurate measurement or public disclosure of the carbon footprint (information is provided to authorities upon request). Notably, the inference phase is typically not covered, despite often dominating real-world energy use. Full transparency is further complicated by complex global supply chains.

While penalties for non-compliance can reach up to 3% of global annual turnover (or €15 million, whichever is higher — Article 101), enforcement capacity remains a concern. Overall, the provision primarily encourages documentation and transparency rather than imposing direct energy reduction targets.

Also appears as a guarantee rule, that "by 2 August 2028 and every four years thereafter, the Commission shall submit a report on the review of the progress on the development of standardisation deliverables on the energy-efficient development of general-purpose AI models, and asses the need for further measures or actions, including binding measures or actions. The report shall be submitted to the European Parliament and to the Council, and it shall be made public." (Article 112. 6.)

3. Risk management for high-risk systems

High-risk AI systems must implement a risk management system (Article 9) throughout their lifecycle. While this system primarily addresses risks to health, safety, and fundamental rights, it may also encompass environmental risks (Article 9 (2) a). However, the environment is not an explicit standalone risk category under the AI Act. The obligations include continuous monitoring, risk assessment, and mitigation measures, but the

approach remains largely procedural, focusing on documentation and internal processes.

A key limitation is that many AI systems with substantial environmental impacts — such as large generative models or foundation models — often do not qualify as high-risk under Annex III, unless they fall into specific use cases (e.g., critical infrastructure). (José Renato Laranjeira de Pereira, 2024.) This gap, combined with potentially broad interpretations by providers, may result in weak implementation. Additionally, there is no mandatory Sustainability Impact Assessment (SIA) or equivalent comprehensive environmental evaluation required for high-risk systems. "Concerning AI-specific regulation, the 2024 AI Act, despite declaring sustainability a main objective, remains partial, inconsistent and mostly limited to transparency provisions." (Ebert et al., 2026. p 5.)

"In 2025, the EU also announced several legislative and strategic measures for early 2026 intended to rearrange its priorities on data centre regulation while also upholding sustainability efforts. This includes the EU Cloud and AI Development Act, which may promote green data centres through expedited permits, a Data Centre Efficiency Package and a Strategic Roadmap for Digitalization and AI in the Energy Sector. The regulatory logic at the EU level, hence, is one of mandatory disclosure, facility level and partially model-level, with a mixed environmental ambition in the Omnibus package and the novel initiatives." (Ebert et al., 2026. p 5.)

4. Voluntary Codes of Conduct

The AI Office and the Member States encourage the development of voluntary codes of conduct that may address, among other things, minimising the environmental impact of AI systems, energy-efficient programming, and sustainable design practices (Article 95 (2) b). These codes are primarily intended for non-high-risk AI systems, although their application can be extended more broadly. Participation is voluntary and open to providers and deployers. (Green Software Foundation, 2026)

Key challenges include the entirely voluntary nature of the codes, which lack any sanctions for non-compliance. This raises concerns about weak uptake and the risk of "greenwashing." Earlier versions of the AI Act (particularly the European Parliament's draft) contained stronger obligations in this area. Many commentators argue that the effectiveness of these codes would be significantly enhanced if combined with mandatory elements.

"This flexible and voluntary approach to sustainability is confirmed by Recital 165, which states that providers and, where applicable, deployers of

all AI systems, whether high-risk or not, and AI models should also be encouraged to voluntarily apply additional requirements related, for example, to elements of the Union's ethical guidelines for trustworthy AI, environmental sustainability. One may be surprised by the European legislator's decision to relegate AI's ecological footprint to a minor or insufficiently serious risk to be subject to a binding obligation, despite the European Union's commitments to carbon neutrality." (Le Goff, T, 2026)

According to Article 112, the European Commission must evaluate the impact and effectiveness of the voluntary codes of conduct — including their environmental sustainability — no later than August 2, 2028. "By 2 August 2028 and every four years thereafter, the Commission shall evaluate and report to the European Parliament and to the Council on the following: (a) the need for amendments extending existing area headings or adding new area headings in Annex III; (b) amendments to the list of AI systems requiring additional transparency measures in Article 50; (c) amendments enhancing the effectiveness of the supervision and governance system." (Article 112. 2.)

According the following regulation by 2 August 2029 and every four years thereafter "the Commission shall submit a report on the evaluation and review of this Regulation to the European Parliament and to the Council. The report shall include an assessment with regard to the structure of enforcement and the possible need for a Union agency to resolve any identified shortcomings. On the basis of the findings, that report shall, where appropriate, be accompanied by a proposal for amendment of this Regulation. The reports shall be made public." (Article 112. 3.)

5. Regulatory sandboxes and innovation support

Regulatory sandboxes allow for the testing of AI systems while taking into account environmental protection, climate change mitigation, and biodiversity. These operate in a controlled environment, making them particularly suitable for developing and testing green AI solutions. However, challenges remain: the number of projects is limited, the process is resource-intensive, and the approach is not yet systematically scalable. (Green Software Foundation, 2024.)

Regulatory sandboxes offer three main benefits: they can help regulators develop better policies, innovators to develop compliant AI products, and consumers by bringing safer products on to the market. In a 2020 report the OECD found they may facilitate dialogue between authorities and new players entering the market. (Attrey et al., 2020, as cited in Marcelin, 2026)

"EU Member States are required to ensure their national competent authorities establish, or participate in, at least one AI regulatory sandbox, which should be operational by 2 August 2026. The AI regulatory sandboxes aim to improve legal certainty to achieve regulatory compliance, support sharing of best practices through fostering cooperation, innovation and competitiveness, contribute to evidence-based regulatory learning and speed up access to the single market. They are accessible on a voluntary basis and include specific measures targeted at SMEs and start-ups." (Marcelin, 2026)

The provisions requires the following. Article 57 (1) the Member States must establish at least one AI regulatory sandbox-which shall be operational by 2 August 2026. That sandbox may also be established jointly with the competent authorities of other Member States. This obligation may also be fulfilled by participating in an existing sandbox in so far as that participation provides an equivalent level of national coverage for the participating Member States. The Commission may provide technical support, advice and tools for the establishment and operation of AI regulatory sandboxes. The aim is to providing a controlled environment for providers to develop, train, validate, and test innovative AI systems (including in real-world conditions) for a limited time under regulatory supervision. According to the principle of cooperation, where appropriate, national competent authorities shall cooperate with other relevant authorities, and may allow for the involvement of other actors within the AI ecosystem. This Article shall not affect other regulatory sandboxes established under Union or national law. Member States shall ensure an appropriate level of cooperation between the authorities supervising those other sandboxes and the national competent authorities. (Article 57. 4.) Competent authorities offer guidance, identify risks (especially to health, safety, and fundamental rights), test mitigation measures, and help ensure compliance with the AI Act and other laws. (Article 57. 6.) Article 58 details functioning, eligibility, sandbox plans, and safeguards. Article 59 allows further processing of personal data in sandboxes for public-interest AI development (with conditions). Article 60 covers real-world testing of high-risk systems outside sandboxes. Broader innovation support (e.g., for SMEs/start-ups) includes reduced regulatory burden, priority access, and use of sandbox results to demonstrate conformity. Environmental aspects can play a role when testing systems developed to safeguard substantial public interests, such as environmental protection or energy sustainability.

Precautionary Approaches within the AI Act

1. Article 40's reference to resource performance and energy efficiency in standards is a procedural nod to sustainability. It encourages (via voluntary/conformity-incentivising standards) better environmental performance of AI systems, which could help mitigate known issues like the high energy and water consumption of training large models. This aligns loosely with precautionary thinking by promoting mitigation of foreseeable environmental impacts through technical standards. (Green Software Foundation, 2024.) Article 40 is only a modest, facilitative step toward greener AI through standardisation; it does not give the precautionary principle the preventive force typical of environmental law (Le Goff, 2026; Pereira, 2024). The Act has accordingly been criticised for "green blind spots," treating environmental sustainability as secondary to other risks. (see further Ibrahim et al., 2026)

2. The energy consumption documentation requirement for General-Purpose AI (GPAI) models under Annex XI (linked to Article 53) represents a modest, transparency-oriented step that aligns only weakly and indirectly with the Precautionary Principle in EU environmental law. Under Article 53(1)(a) and Annex XI, Section 1(2)(e), providers of all GPAI models must include in their technical documentation: the known or estimated energy consumption of the model. If exact figures are unknown, estimates may be based on computational resources used (e.g., FLOPs, training time, infrastructure details).

This documentation must be kept up-to-date, provided to the AI Office/national authorities upon request (with some exceptions for qualifying open-source models), and shared in summarized form with downstream providers integrating the model (via Annex XII). It focuses primarily on the training/development phase, though broader lifecycle considerations appear in related standardisation efforts. Systemic-risk GPAI models face additional obligations (e.g., risk assessment and mitigation under Article 55), where energy/compute factors can inform classification via Annex XIII criteria, but environmental harm is not a core trigger.

There is a limited alignment tot he precautionary principle, if transparency can work as a precautionary tool. Requiring documentation promotes awareness of AI's significant energy footprint (training large models can consume enormous resources, with inference adding more over time). This enables better-informed decisions by regulators, downstream

users, and the public, indirectly supporting mitigation and aligning with precautionary goals of anticipation and informed risk management. It ties into Article 40's push for harmonised standards on resource performance and energy-efficient development of GPAI models, encouraging long-term improvements via standardisation.

This provision is a facilitative transparency measure that nudges toward better environmental accountability but falls short of fully embodying the precautionary principle's demand for proactive, uncertainty-driven prevention and minimization of potential serious harm. It reflects the AI Act's overall "green blind spots," treating sustainability as supportive rather than central. Stronger alignment would require mandatory full-lifecycle assessments, binding efficiency thresholds, or clearer integration of environmental risks into the risk-based framework.

3. The Article 9's mandatory risk management system for high-risk AI systems is a strong and appropriate embodiment of the precautionary principle—particularly when applied to risks to health, safety, and fundamental rights—though its alignment is weaker and more indirect regarding environmental risks. Article 9 mandates that providers of high-risk AI systems establish, implement, document, and maintain a risk management system as a continuous, iterative process throughout the entire lifecycle of the system. The continuous, iterative nature across the full lifecycle embodies anticipation and ongoing vigilance—key precautionary traits. It requires addressing reasonably foreseeable risks even without full certainty.

Providers must reduce risks "as far as possible" and ensure residual risks are acceptable, aligning with the principle's emphasis on prevention and proportionality. (see also Fraser H., 2024) It places the responsibility on developers to identify, assess, and mitigate risks ex-ante and ongoing, similar to precautionary approaches in product safety or chemicals regulation. This makes Article 9 one of the more precautionary elements of the AI Act for the risks it explicitly covers (health, safety, fundamental rights).

The narrow scope of risks poses some challenges. The provision specifically targets risks to health, safety or fundamental rights. Environmental impacts (e.g. energy consumption, carbon footprint, resource depletion, e-waste) are not directly included as stand-alone risks in Article 9, contrary to some previous parliamentary proposals.

Environmental considerations may enter indirectly (e.g., via fundamental rights interpretations that include environmental protection under the

Charter (Charter art. 37), or through post-market monitoring). However, critics argue this is insufficient for the uncertain but potentially serious long-term environmental harms of AI. (see further Le Goff, T., 2026) There are no absolute prevention under the regulation. It allows "acceptable" residual risks and focuses on mitigation rather than outright prohibition in cases of high uncertainty, which is more aligned with a proportionate risk-based approach than the strongest versions of precaution. (Meyers, Z., 2025, p 149).

Article 9 is highly appropriate and precautionary for the AI Act's primary objectives (protecting people from AI-driven harms to health, safety, and rights). It operationalizes anticipation, iteration, and minimization effectively. However, in the environmental context (consistent with prior questions on Article 40 and GPAI energy documentation), it provides only limited, indirect alignment because environmental risks are not explicitly integrated into the core risk management obligations. Stronger precautionary environmental protection would require explicit inclusion of lifecycle environmental impacts in Article 9 or complementary mandatory assessments. This reflects the AI Act's overall prioritization of human-centric risks while treating sustainability as a secondary concern.

4. The Voluntary Codes of Conduct under Article 95 of the EU AI Act align only weakly and indirectly with the precautionary principle, especially in the environmental context. They represent a facilitative, soft-law approach rather than a robust precautionary mechanism.

Article 95's Voluntary Codes of Conduct offer a modest, encouraging step toward precautionary environmental governance through flexibility and best-practice promotion, but they fall short of the principle's demand for proactive, binding prevention when serious risks are uncertain. They function more as a complementary soft-law tool to support innovation and voluntary uptake rather than a core precautionary instrument. Stronger alignment would require making key environmental elements mandatory or tying them to enforceable standards. "Subjecting systems with a significant environmental footprint, or even all high-risk AI systems, to a mandatory environmental assessment could also contribute to reducing this footprint." (Le Goff, T, 2026, p.6.)

5. Regulatory sandboxes and innovation support measures (primarily Articles 57–60 and Chapter VI of the EU AI Act) align only partially and indirectly with the precautionary principle. They prioritize innovation-friendly experimentation under supervised conditions rather than embodying strong, proactive prevention of uncertain environmental harms.

Sandboxes require ongoing risk assessment and mitigation for identified significant risks to health, safety, and fundamental rights. This supports precautionary anticipation and learning in a controlled setting, potentially extending to environmental considerations in relevant use cases.

Regulatory sandboxes and innovation support are appropriate for balancing innovation with supervised risk management but provide only weak to moderate alignment with the Precautionary Principle — particularly on environmental issues. They are facilitative and learning-oriented rather than strongly preventive or uncertainty-driven in the environmental domain. This fits the AI Act's broader pattern: robust precaution for core human risks, but softer, procedural approaches to sustainability. Effectiveness will depend on national implementation and how environmental criteria are applied in practice.

The Risk-Based Regulatory Framework as Precautionary Regulation

As highlighted in the introduction, the AIA includes several provisions that reflect the precautionary principle, even though their environmental effects are largely indirect. In the following, we highlight some of these provisions

The EU AI Act establishes a risk-based regulatory framework that implicitly applies the precautionary principle — preventing potential harm even amid scientific uncertainty, particularly for high-risk AI. It categorises AI systems into four risk levels: unacceptable, high, limited, and minimal/zero risk. This approach places risk identification and management at the core of regulation, even without full scientific certainty. The prohibition of unacceptable-risk systems further embodies the precautionary principle. The Act bans AI applications posing significant threats to fundamental rights, security, or European values, such as subliminal manipulation techniques, social scoring systems, and real-time remote biometric identification in public spaces (with limited law enforcement exceptions). These bans act as preventive measures against technologies that could cause serious and irreversible harm. (Article 5 – *Prohibited AI practices*)

The strict regulation of high-risk systems also reflects a precautionary approach. For high-risk AI systems (e.g. biometric identification, AI used in critical infrastructures, education or employment decision-making), the AI Act imposes strict requirements, such as: risk assessment and mitigation measures, transparency and documentation obligations, third-party

conformity assessments before entering the market. (Article 6 *Classification rules for high-risk AI systems*)

Continuous monitoring and reporting during use is a key obligation. This approach is a practical application of the precautionary principle, as the regulation aims to minimise potential harm, even if its exact probability or nature is uncertain. The Commission stresses that risk management involves both political and normative decisions, which is in line with the precautionary principle's view that determining the level of risk that is acceptable to society is not a purely technical matter. (Article 17, 19, 26, 72, 73)

Systems such as chatbots or deepfakes are subject to transparency requirements (e.g. users must be informed that they are communicating with AI). This is also done in the spirit of precaution, as it aims to maintain trust and avoid potential abuse. On the one hand, the precautionary approach manifests itself in the fact that it prescribes preventive measures. Rigorous pre-testing and approval of high-risk systems ensures that the technology is only brought to market when the risks can be managed. On the other hand, it requires proper supervision. Post-market monitoring of systems allows for quick intervention if unexpected problems arise. (Article 13, 50)

The use of a normative approach is also a precautionary measure**.** The determination of the acceptable level of risk takes into account social, ethical and political considerations, as required by the precautionary principle. (see Fraser H. - Bello y Villarino, 2024, p.431-446.)

Closing Thoughts – Conclusions

This proactive approach may help prevent the development and deployment of harmful AI systems. However, the power of the precautionary principle to influence the development of AI largely resides in whether other major regulators adopt the same approach.

Environmental sustainability is relegated to the status of non-binding obligations within voluntary codes of conduct, rendering it a somewhat neglected element of the Regulation despite its acknowledged importance and the European institutions' broader ecological objectives. However, the Regulation does impose documentation obligations regarding the energy consumption of certain high-risk AI systems. (see more about this Le Goff, T., 2026)

The EU AI Act is an ambitious attempt to regulate AI on a risk-based basis, but the precautionary principle shows significant shortcomings in its environmental dimension. While the legislator acknowledges the ecological

footprint of AI (high energy and water consumption, e-waste), it largely limits sustainability to voluntary and procedural tools (Article 40 standards, Annex XI documentation, Article 95 codes) rather than mandatory, measurable obligations. This contrasts with the high level of protection enshrined in the EU Green Deal and Article 191 TFEU, where the precautionary principle requires the prevention of irreversible damage even in the face of scientific uncertainty.

The strong human rights and safety focus of the regulation (Article 9) is commendable, but the failure to integrate environmental risks – especially in the case of high-impact GPAI models – leaves "green blind spots". Harmonised standards and sandboxes have a positive role in supporting innovation, but they do not in themselves guarantee real emission reductions or full life cycle analysis. Voluntary codes of conduct could have a risk of greenwashing, while the urgent nature of the climate crisis would require stronger, mandatory mechanisms (e.g. mandatory SIAs, carbon quotas or public footprint disclosure). Overall, the AI Act aims for global leadership, but remains more of an aspiration than an obligation when it comes to sustainability. The 2028 review (Article 112) is a critical opportunity for correction. For AI to truly serve to protect the planet for future generations, the legislator needs to go beyond voluntarism: integrate environmental risks into the central risk management framework, introduce mandatory transparency and efficiency thresholds, and closely link the digital and green transitions. Only in this way can the precautionary principle be fully implemented in the AI era, preventing both technological and ecological disasters. The EU must act now to ensure that innovation does not come at the expense of the planet.

In summary, the AI Act provides a framework, but sustainability remains more of an aspiration than an obligation. To become truly green, it must move beyond voluntarism towards measurable, enforceable mechanisms. Only then can AI truly serve planetary protection for future generations.

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33. Acronyms

34. CEN – Comité Européen de Normalisation (European Committee for Standardization)
35. CENELEC – Comité Européen de Normalisation Électrotechnique (European Committee for Electrotechnical Standardization)
36. ESO – European standardisation organisation
37. GPAI – general-purpose AI
38. LCA – life-cycle assessment