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CONTRADICTIONS OF TWIN TRANSITIONS: THE ENVIRONMENTAL IMPACT OF AI SYSTEMS FROM THE EUROPEAN UNION PERSPECTIVE

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The paper examines the environmental impact of AI systems from the perspective of the European Union, placing the issue within the broader context of the twin transitions, namely the green transition and digital transition, promoted by European institutions through various initiatives, policies and legislative acts. As an introduction, some data on the environmental impact of AI systems will be presented, followed by an analysis of the relevant European legal framework, and concluding with a discussion of the opportunities offered by the digital transition, specifically through AI, in order to identify potential solutions to the challenges outlined.

Keywords: Twin Transitions; AI Systems; Environmental Impact; EU Regulatory Framework; Challenges & Opportunities.

I. INTRODUCTORY PREMISES

In the present moment, the European Union is facing a complex challenge, identified in the increasing use of Artificial Intelligence systems by all social actors, to which it is attempting to respond through various policies and initiatives. However, these measures only partially harness the potential of technological advancement for environmental sustainability and, in most cases, fail to contain the negative effects of Artificial Intelligence use on the environment. Accordingly, the present research aims to demonstrate this regulatory gap and to analyze its implications from a legal and factual perspective, with a view to examining possible strategies to address the highlighted challenges.

As a preliminary step, some definitions must be provided. First and foremost, the term Artificial Intelligence (hereinafter AI) refers to a type of Information and Communication Technology (hereinafter ICT), capable of performing tasks typical of human cognitive functions, with the aim «to generate outputs such as content, predictions, recommendations, or decisions which influence the environment with which the system interacts, be it in a physical or digital dimension»[1]. This definition has also been endorsed by the European

[1] See C. A. Ciaralli, *Intelligenza artificiale, decisione politica e transizione ambientale: sfide e prospettive per il costituzionalismo*, available at https://federalismi.it/nv14/articolo-documento.cfm?artid=49045 (last visited Jul. 24, 2025), p. 44 ff.; C. Di Francesco Maesa, *Economia circolare e IA: a che condizioni è una sfida possibile per l'UE?*, available at

Commission, which describes AI as a set of «systems that display intelligent behavior by analyzing their environment and taking actions – with some degree of autonomy – to achieve specific goals»[2].

Against the backdrop briefly described – characterized by both the growing use of AI and the European Union's partial regulatory response – the concept of the twin transitions has emerged, namely the green and digital transition, two key objectives that have shaped European policy in recent years. When examined in relation to each other, these transitions necessarily prompt a more in-depth reflection on technological progress, particularly regarding the environmental impact of AI. Indeed, the practical application of AI tools across various economic and industrial sectors has led to clear simplifications and efficiencies, for example in terms of resource management optimization, automation of repetitive processes, investment predictability and personalization of products and services offered to the public. Nevertheless, at the same time, the implementation of such technologies carries multiple risks with significant consequences for human life and health, foremost among them the environmental concerns, that this research seeks to explore. In this regard, the physical dimension of AI involves data centers, namely fiber optic cables and other infrastructure spread across various parts of the globe, that enable both the training and subsequent functioning of AI. However, these infrastructures require enormous amounts of energy and water to operate and to be cooled effectively.

The tangible nature of these environmental issues becomes clear when considering aspects such as the underwater space through which cables are laid, the airspace used for data transmission via satellites and antennas, the territories where raw materials and valuable natural resources are extracted, or the areas where electronic waste is deposited, added to the massive consumption of water and energy at the expenses of developing countries[3].

It is therefore clear that the scenario outlined above contributes to worsening climate change, which has now become an increasingly serious and urgent issue. This is evidenced by extreme weather events, such as droughts, wildfires, flooding and sea-level rise: all phenomena that are expected to increase further in the coming years as the global temperatures continue to rise above pre-industrial levels (currently at 1.1°C). This trend persists despite a 2018 report

https://www.aisdue.eu/costanza-di-francesco-maesa-economia-circolare-e-ai-a-che-condizionie-una-sfida-possibile-per-lue/ (last visited Jul. 24, 2025), p. 5 ff.; European Commission, *Proposal for a Regulation of the European Parliament and of the Council Laying Down Harmonised Rules on Artificial Intelligence (Artificial Intelligence Act) and Amending Certain Union Legislative Acts*, 21.4.2021, COM(2021) 206 final, p. 18, par. 6; A. Nordgren, *Artificial intelligence and climate change: ethical issues*, available at https://www.emerald.com/jices/article/21/1/1/432616/Artificial-intelligence-and-climate-change-ethical (last visited Jul. 24, 2025), p. 2 f.; A. L. Stein, *Artificial Intelligence and Climate Change*, available at https://scholarship.law.ufl.edu/facultypub/996/ (last visited Jul. 24, 2025), p. 891 ff.; L. G. Sciannella, *Intelligenza artificiale, politica e democrazia*, available at https://www.dpceonline.it/index.php/dpceonline/article/view/1577 (last visited Jul. 24, 2025), p. 338 ff.

[2] European Commission, *Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions. Artificial Intelligence For Europe*, 25.4.2018, COM(2018) 237 final, p. 1.

[3] For an overview of the environmental issues caused by AI, see P. Li, J. Yang, M. A. Islam, S. Ren, *Making AI Less "Thirsty": Uncovering and Addressing the Secret Water Footprint of AI Models"*, available at https://arxiv.org/pdf/2304.03271 (last visited Jul. 24, 2025).

by the United Nations Intergovernmental Panel on Climate Change (IPCC), which emphasized that limiting global warming to 1.5°C is absolutely essential in order to reduce the impact of climate change on ecosystems, human health, and overall well-being[4].

As previously mentioned, the search for a balance between the twin transitions has become a crucial issue for the European Union, which has responded through a series of measures aimed at reducing the environmental impact of technological progress. The strategy implemented by the EU to address these challenges is grounded in a change of perspective on environmental matters, including in daily life habits, that emphasizes the importance of adopting long-term solutions capable of generating positive effects over time, to the benefit of future generations[5].

[4] Intergovernmental Panel on Climate Change (IPCC), *Special Report: Global Warming of 1.5°C*, available at https://www.ipcc.ch/sr15/ (last visited Jul. 24, 2025), Chapter 3. Further insights on climate change and environmental protection can be found in U. Beyerlin, J. Grote Stoutenburg, *Environment, International Protection*, in R. Wolfrum (under the direction of), *The Max Planck Encyclopedia*, p. 461-483 (Vol. II, Oxford University Press, Oxford, 2012); G. Cataldi, *Ambiente (tutela dell') (DCE)*, in *Enc. giur. Treccani*, p. 1 ff. (Vol. IV, Istituto della Enciclopedia italiana, Roma, 2004); M. Gestri, *Ambiente (dir. int.)*, in S. Cassese (diretto da), *Diz. dir. pubbl.*, p. 214-229 (Vol. I, Giuffrè, Milano, 2006); O. C. Ruppel, *Intersections of Law and Cooperative Global Climate Governance – Challenges in the Anthropocene*, in O. C. Ruppel, K. Ruppel-Schlichting, C. Roschmann (eds.), *Climate Change: International Law and Global Governance: Volume II: Policy, Diplomacy and Governance in a Changing Environment*, p. 35-100 (1st ed., Nomos Verlagsgesellschaft mbH, 2013), available at http://dx.doi.org/10.5771/9783845242774 (last visited Jul. 30, 2025); P. J. Sands, I. Millar, *Climate, International Protection*, in R. Wolfrum (under the direction of), *The Max Planck Encyclopedia*, p. 236-247 (Vol. II, Oxford University Press, Oxford, 2012); P. Sands, J. Peel, A. Fabra, R. MacKenzie, *Principles of International Environmental Law*, p. 195 ff. (4th ed., Cambridge University Press, Cambridge, 2018); G. Tamburelli, *Ambiente (tutela dell') (dir. int.)*, in *Enc. giur. Treccani*, p. 1 ff. (Vol. IV, Istituto della Enciclopedia italiana, Roma, 2004).

[5] On these topics, see European Commission, *Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee, the Committee of the Regions and the European Investment Bank. A Clean Planet for All. A European Strategic Long-Term Vision for a Prosperous, Modern, Competitive and Climate Neutral Economy*, 28.11.2018, COM(2018) 773 final e V. Zampaglione, *Climate change: towards global law?*, available at https://universitypress.unisob.na.it/ojs/index.php/ejplt/article/view/2100 (last visited Jul. 24, 2025), p. 2 ff., which highlights the need to address climate change through shared principles and rules. As for environmental sustainability, policies aimed at sustainable development, with the dual objective of preserving ecosystems to meet the needs of both the present and the future, date back to earlier times, originating with the 1987 Brundtland Report *Our Common Future*, published by the World Commission on Environment and Development (WCED).
Over the years, key milestones have included the Conference of the Parties (COP), which have gained increasing influence on climate matters and led to the adoption of a universal climate agreement at COP21 in 2015 (*Paris Agreement*), later renewed in 2021 through the *Climate Pact* at COP26 in Glasgow.
For an overview of these topics, see G. Cataldi, *Ambiente (tutela dell') (DCE)*, cit., p. 1 ff.; M. Gestri, *Ambiente (dir. int.)*, cit., p. 215 ff. See also M. C. Gaeta, *Intelligenza artificiale sostenibile e tutela dei green rights*, available at https://universitypress.unisob.na.it/ojs/index.php/ejplt/article/view/2055 (last visited Jul. 24, 2025), p. 150 ff., which also references the UN 2030 Agenda for Sustainable Development (*Transforming Our World: the 2030 Agenda for Sustainable Development*), signed by the governments of the 193 UN Member States in September 2015 and comprising 17 Sustainable Development Goals (SDGs).
The full text is available on the official website of the United Nations at the following link: https://sdgs.un.org/2030agenda. A more recent interpretation of environmental sustainability is the one that emphasizes the shift from a linear economy model to a circular economy model. On this topic, see, among others, E. Chiti, *Verso una sostenibilità plurale? La forza trasformatrice del Green Deal e la direzione del cambiamento giuridico*, in Riv. quadr. dir. amb. (III, 2021); A. D'Aloia, *Prefazione*, in M. Cocconi (a cura di), *La regolazione dell'economia circolare: sostenibilità e nuovi paradigmi di sviluppo*, 9-12 (Franco Angeli, Milano, 2020).

II. THE ENVIRONMENTAL COSTS OF AI

Before delving into the policies and initiatives adopted by the European Union in the context of the green and digital transition, the following section presents some data concerning environmental pollution caused by the implementation of AI technologies, data that help underscore the urgency of addressing these issues, which can no longer be overlooked.

From the design phase onward, it must be acknowledged that the development of AI systems entails significant environmental costs, primarily linked to the extensive use of natural resources. Over the past fifty years, global resource extraction has tripled, a trend expected to continue in the coming decades. In particular, the production of AI hardware and related infrastructure relies on the extraction of rare and valuable raw materials – such as cobalt, palladium, silver, gold, indium, lithium and aluminum – with the associated environmental and social repercussions, especially in developing countries. In fact, these impacts are often felt in regions hosting resource extraction and data center infrastructures, frequently located outside high-income countries, resulting in damage to local ecosystems and the depletion of natural resources[6].

Moreover, the production of the devices necessary for AI operation involves not only the extraction of raw materials, which, as mentioned, is already environmentally harmful, but also the environmental cost of transporting these materials: from the mining sites to component manufacturing facilities, then to other factories where the end-products are assembled, and finally to the AI developers and users. As is evident, each step in the production chain results in greenhouse gas emissions, which must therefore be counted among the total emissions attributable to AI[7].

For what concerns the functioning of AI systems, then, the servers on which they rely generate massive energy consumption. This is due to the need to power extremely powerful machines capable of performing highly complex computations, consumption which, in turn, results in significant greenhouse gas emissions, thereby contributing to global warming.

Some of the already recorded data on energy consumption are as follows: in 2018, the global energy consumption of data centers across the entire ICT sector rose to 205 TWh, accounting for approximately 1% of global electricity use; this consumption increased to 460 TWh in 2022. According to some estimates, by 2026, the total electricity consumption caused by data centers could exceed 1,000 TWh, roughly equivalent to the total electricity consumption of Japan[8].

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[6] C. Di Francesco Maesa, *Economia circolare e IA*, cit., p. 15 ff. For relevant data on the subject, see H. Roberts, J. Zhang, B. Bariach et al., *Artificial intelligence in support of the circular economy: ethical considerations and a path forward*, available at https://link.springer.com/article/10.1007/s00146-022-01596-8 (last visited Jul. 24, 2025), p. 1451.

[7] In this sense, K. Crawford, *Atlas of AI: Power, Politics, and the Planetary Costs of Artificial Intelligence*, 23-51 (Yale University Press, New Haven and London 2021); A. Nordgren, *Artificial intelligence and climate change*, cit., p. 3 f.

[8] The figures mentioned are the estimates of the International Energy Agency, *Electricity 2024. Analysis and forecast to 2026*, available at https://www.iea.org/reports/electricity-2024 (last visited Jul. 24, 2025), p. 8. See also F. Camisa, *Ambiente e tecnologia: l'interconnessione tra le 'transizioni gemelle'*, available at https://www.federalismi.it/nv14/articolo-documento.cfm?artid=50685 (last visited Jul. 24, 2025), p. 61 ff.; E. Masanet, A. Shehabi, N. Lei, S. Smith, J. Koomey, *Recalibrating global data center energy-use estimates. Growth in energy use has slowed owing to efficiency gains that smart policies can help maintain in the near term,* available at

Another critical issue closely connected to energy consumption is the enormous water usage required by AI models. Water is first used to generate the electricity needed to power these systems and is thereafter required to cool the servers; by way of example, as early as 2023, one study estimated that ChatGPT consumed approximately 500 ml of water for every 20 to 50 simple question-and-answer interactions. This level of consumption must be understood in the context of increasing global water scarcity and unequal distribution, which threaten water security worldwide[9].

Regarding greenhouse gas emissions, studies based on 2015 data have already shown that the ICT sector was responsible for 1.4% of global greenhouse gas emissions a decade ago. According to some estimates, this percentage could rise to as much as 23% by 2030. One study specifically focusing on AI as a contributor to climate change revealed that training a single AI model for Natural Language Processing (NLP) generates approximately 300,000 kg of carbon dioxide, approximately equivalent to the emissions of 125 round-trip flights from New York to Beijing[10].

Beyond the operational phase, the final stage in the life cycle of AI systems – the disposal of electronic devices – raises additional environmental concerns related to the improper handling of electronic waste (e-waste). Several studies have confirmed that, in most cases, electronic waste, including that generated by AI technologies, is neither properly disposed of nor adequately recycled, releasing toxic substances into ecosystems with serious consequences for both human health and the environment. According to recent research, only 22% of electronic waste is recycled in an environmentally sustainable manner: this raises the critical question of what happens to the remaining portion, which unfortunately represents the vast majority of discarded material[11].

III. AI WITHIN THE EUROPEAN LEGAL FRAMEWORK: THE DELICATE RELATIONSHIP BETWEEN THE TWIN TRANSITIONS

The European Union's action in the field of environmental sustainability is based on specific provisions of the Treaty on the Functioning of the European Union (TFEU), in particular

https://www.science.org/doi/10.1126/science.aba3758 (last visited Jul. 24, 2025), p. 984-986; A. L. Stein, *Artificial Intelligence and Climate Change*, cit., p. 917 f.

[9] C. Di Francesco Maesa, *Economia circolare e IA*, cit., p. 10 ff.; P. Li, J. Yang, M. A. Islam, S. Ren, *Making AI Less "Thirsty"*, cit., p. 5 ff.

[10] For the study mentioned see M. Coeckelbergh, *AI for climate: freedom, justice, and other ethical and political challenges*, available at https://link.springer.com/article/10.1007/s43681-020-00007-2 (last visited Jul. 24, 2025), p. 68 f. On these topics see also A. S. G. Andrae, T. Edler, *On Global Electricity Usage of Communication Technology: Trends to 2030*, available at https://www.mdpi.com/2078-1547/6/1/117 (last visited Jul. 24, 2025), p. 143 f.; J. Cowls, A. Tsamados, M. Taddeo, L. Floridi, *The AI gambit*, cit., p. 290 ff.; J. Malmodin, D. Lundén, *The Energy and Carbon Footprint of the Global ICT and E&M Sectors 2010–2015*, available at https://www.mdpi.com/2071-1050/10/9/3027 (last visited Jul. 24, 2025), p. 1 ff.; A. Nordgren, *Artificial intelligence and climate change*, cit., p. 3 f.; A. van Wynsberghe, *Sustainable AI: AI for sustainability and the sustainability of AI*, available at https://link.springer.com/article/10.1007/s43681-021-00043-6 (last visited Jul. 24, 2025), p. 213 f.

[11] C. P. Baldé, R. Kuehr, T. Yamamoto et al., *The Global E-Waste Monitor 2024*, available at https://ewastemonitor.info/wpcontent/uploads/2024/03/GEM_2024_1803_web_page_per_page_web.pdf (last visited Jul. 24, 2025); F. Camisa, *Ambiente e tecnologia*, cit., p. 59; C. Di Francesco Maesa, *Economia circolare e IA*, cit., p. 13 ff.; M. C. Gaeta, *Intelligenza artificiale sostenibile*, cit., p. 148 ff.

Article 11 and the articles contained in Title XX (artt. 191-193), which are explicitly dedicated to the Union's environmental policies. Article 11 TFEU, confirming the principles already expressed in Article 37 of the Charter of Fundamental Rights of the European Union (Nice Charter), states that environmental protection requirements must be integrated into the definition and implementation of the Union's other policies and activities (integration principle), particularly with a view to promoting sustainable development. Article 191(1) TFEU further sets out the objectives of environmental policy, including the protection of human health, the prudent and rational use of natural resources, the promotion of international measures to tackle environmental problems at regional or global level and, notably, the fight against climate change[12].

However, the legal foundations mentioned are proving to be insufficient and outdated in addressing the new environmental challenges posed by the climate emergency, which the European Union could confront more effectively only if the Treaties were revised and supplemented with more detailed and binding provisions in this field. Furthermore, Article 11 TFEU and Article 37 of the Charter, lay down criteria for assessing the EU's activities that are too vague to allow individuals to determine whether, in environmental matters, the European institutions have complied with the principle of integration between environmental protection and the European policies and initiatives[13].

Despite these normative shortcomings, the EU has taken targeted measures to respond to the environmental impacts of digitalization, embedding them within the broader twin transition strategies, with the *European Green Deal* and *Europe's Digital Transformation* serving as foundational pillars of the Commission's 2019-2024 agenda.

Firstly, on 11 December 2019 the European Commission presented the *European Green Deal* (hereinafter also EGD), a package of measures aimed at achieving climate neutrality by 2050. This goal is to be reached through a compensation mechanism intended to offset greenhouse gas emissions with their simultaneous absorption by forests, alongside biodiversity conservation, decarbonization, promotion of the circular economy[14], and the development

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12 A. Festa, *Verso l'obiettivo climatico del 2030: su alcuni sviluppi attuativi del Green Deal europeo attraverso norme vincolanti. Il pacchetto "Fit for 55%"*, available at https://rivista.eurojus.it/wp-content/uploads/pdf/qui-35.pdf (last visited Jul. 24, 2025), p. 119 ff.; M. C. Gaeta, *Intelligenza artificiale sostenibile*, cit., p. 151 ff. For a detailed examination of the aforementioned articles, see S. Amadeo, *Art. 11 TFUE*, in A. Tizzano (a cura di), *Trattati dell'Unione europea*, p. 407-414 (2nd ed., Giuffrè, Milano, 2014); *Id.*, *Art. 191 TFUE*, *ibid.*, p. 1616-1637; *Id.*, *Art. 192 TFUE*, *ibid.*, p. 1638-1647; *Id.*, *Art. 193 TFUE*, *ibid.*, p. 1647-1650; M. Onida, *Art. 37 Carta*, in R. Mastroianni, O. Pollicino, S. Allegrezza, F. Pappalardo, O. Razzolini (a cura di), *Carta dei diritti fondamentali dell'Unione europea*, p. 691-707 (Giuffrè, Milano, 2017); P. A. Pillitu, *Art. 11 TFUE*, in F. Pocar, M. C. Baruffi (a cura di), *Commentario breve ai Trattati dell'Unione europea*, p. 173-175 (2nd ed., CEDAM, Padova, 2014); *Id.*, *Art. 191 TFUE*, *ibid.*, p. 1107-1112; *Id.*, *Art. 192 TFUE*, *ibid.*, p. 1112-1115; *Id.*, *Art. 193 TFUE*, *ibid.*, p. 1115-1116; *Id.*, *Art. 37 Carta*, *ibid.*, p. 1752. Moreover, according to authoritative scholarship, within the European legal framework the tension between economic development objectives and environmental protection should be addressed through the integration principle enshrined in Article 11 TFEU. This provision, in fact, confirms the cross-cutting nature of environmental protection and allows for a reconciliation of these competing interests from the perspective of sustainable development, by integrating environmental concerns into the European Union's policies across various economic sectors. In this regard, see again S. Amadeo, *Art. 11 TFUE*, *ibid.*, p. 408 f.

13 S. Amadeo, *Art. 11 TFUE*, *ibid.*, p. 411.

14 For the gradual shift from the linear economy paradigm to that of the circular economy in the context of the ecological transition, see M. Cocconi, *Il mosaico dell'economia circolare: Regole, principi, modelli*, 25 ff. (Franco Angeli,

of clean technologies, thus reducing environmental impact and safeguarding citizens' health[15].

More specifically, with a view to fostering economic and technological growth based on sustainability, the European Commission defined the EGD as **«**a new growth strategy aimed to transform the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy, where there are no net emissions of greenhouse gases in 2050 and where economic growth is decoupled from resource use**»**[16]**.**

Shortly after its adoption, the trajectory of the European Green Deal intersected with the outbreak of the COVID-19 pandemic. In response, during the summer of 2020, the European Union launched the *EU Recovery Plan* (known as *Next Generation EU*, or NGEU), a major recovery initiative designed to help Member States address the economic and social consequences of the pandemic, with a strong focus on promoting a greener and more digital Europe. Along the same lines, as an integral part of the Green Deal, in July 2021 the European Commission adopted *Fit for 55*, a package of proposals aligned with the aforementioned climate goals, with the specific aim of reducing greenhouse gas emissions by at least 55% by 2030. These projects, which position Europe as a global leader in the fight against climate change, were reaffirmed following the installation of the new Commission in 2024[17].

As for the digital transition, even prior to the pandemic, the European Union had already set itself the ambitious goal of achieving digital leadership, seeking to create the conditions necessary to make the Union technologically competitive while also respecting citizens' safety[18].

Milano, 2023); M. Montini, *Quali principi giuridici per l'economia circolare nell'Unione europea?*, available at https://www.dpceonline.it/index.php/dpceonline/article/view/2032 (last visited Jul. 24, 2025); L. Ricci, *La triade "rigenerazione, ambiente e consumo" nel "modello circolare"*, in Riv. quadr. dir. amb. (II, 2023).

15 European Commission, *Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions. The European Green Deal*, 11.12.2019, COM(2019) 640 final. On the *European Green Deal* see M. C. Carta, *Il Green Deal europeo. Considerazioni critiche sulla tutela dell'ambiente e le iniziative di diritto UE*, available at https://rivista.eurojus.it/wp-content/uploads/pdf/Il-Green-Deal-europeo.pdf (last visited Jul. 24, 2025); E. Chiti, *Managing the ecological transition of the EU: The European Green Deal as a regulatory process*, in Riv. quadr. dir. amb. (I, 2021); *Id.*, *Verso una sostenibilità plurale?*, cit.; E. Chiti, D. Bevilacqua, *Green Deal. Come costruire una nuova Europa*, 1 ff. (il Mulino, Bologna, 2024); J. Cowls, A. Tsamados, M. Taddeo, L. Floridi, *The AI gambit*, cit., p. 298 ff.; L. Fisher, *Challenges for the EU Climate Change Regime*, available at https://www.cambridge.org/core/journals/german-law-journal/article/challenges-for-the-eu-climate-change-regime/2AF8CF1DCFFBC5A2C4F5CC0E95D1310C (last visited Jul. 24, 2025), p. 5 ff.; M. E. Harris, *The normative values of the European Green Deal*, available at https://rivista.eurojus.it/wp-content/uploads/pdf/The-normative-values-of-the-Green-Deal.pdf (last visited Jul. 24, 2025); M. Montini, *La condizionalità della duplice transizione verde e digitale nel Recovery Fund dell'Unione europea*, available at https://www.rivistaianus.it/forum/covid-19/2020_06_26_Montini.pdf (last visited Jul. 24, 2025), p. 1 ff.; M. Onida, *Il Green Deal europeo*, in P. Manzini, M. Vellano (a cura di), *Unione europea 2020. I dodici mesi che hanno segnato l'integrazione europea*, 257-283 (Wolters Kluwer, Milano, 2021); C. Pesce, *Il Green Deal europeo e la neutralità climatica entro il 2050*, in L. F. Pace (a cura di), *Quo vadis Europa? Le sfide dell'Unione europea nel tempo delle crisi. Una riflessione multidisciplinare nel contesto della Conferenza sul futuro dell'Europa*, 359-371 (Edizioni Efesto, Roma, 2023).

16 European Commission, *The European Green Deal*, cit., p. 2.

17 F. Camisa, *Ambiente e tecnologia*, cit., p. 66; C. A. Ciaralli, *Intelligenza artificiale*, cit., p. 72; M. C. Gaeta, *Intelligenza artificiale sostenibile*, cit., p. 151 ff.; A. Festa, *Verso l'obiettivo climatico del 2030*, p. 122 ff.

18 J. Cowls, A. Tsamados, M. Taddeo, L. Floridi, *The AI gambit*, cit., p. 298 ff.; M. Montini, *La condizionalità della duplice transizione*, cit., p. 1 ff. See also European Commission, *Communication from the Commission to the European*

Given its dual nature, the digital transition must be closely linked to the green transition to ensure a balanced regulatory framework that reconciles environmental protection with technological development: whereas the green transition aims for climate neutrality by 2050 and emission reductions, rapid technological advancement inevitably contributes to carbon dioxide emissions, environmental waste, and global warming[19].
The need to integrate the EGD with the digital transition through the sustainable use of digital technologies was reiterated by the Commission in subsequent communications. Of particular note is the communication *Shaping Europe's Digital Future* of 19 February 2020, which emphasized how digital solutions can support the sustainability objectives of the green transition by promoting the circular economy, supporting the decarbonization of all sectors, and reducing the environmental and social footprint of products placed on the EU market[20]. This was followed by the *2022 Strategic Foresight Report: Twinning the green and digital transitions in the new geopolitical context*, issued in June 2022, which further addressed these same themes[21].
In light of these considerations, one can conclude by reinforcing the European Union's perspective that the regulation of the two transitions must be addressed jointly, through an integrated and synergistic approach in which the goals pursued by both are balanced and aligned[22].

IV. The Implementation of the European Green Deal and AI

In the EGD, as previously mentioned, technological progress is intended to support long-term environmental sustainability. The communication explicitly states that digital technologies, including AI, «can accelerate and maximize the impact of policies to deal with climate change and protect the environment»[23]. This assertion was further supported in the *New Circular Economy Action Plan* of 11 March 2020, which added that new technologies,

Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Commission Work Programme 2020. A Union that strives for more, 29.1.2020, COM(2020) 37 final.
[19] F. Camisa, *Ambiente e tecnologia*, cit., p. 56 ff. On the convergence between the green and digital transitions, see M. Orofino, *La tutela dell'ambiente nella costruzione della società digitale europea*, in ASTRID Rassegna 387 (IV, 2024); M. Passalacqua, *Green deal e transizione digitale. Regolazione di adattamento a un'economia sostenibile*, in An. Giur. Ec. (I, 2022).
[20] In this sense, see European Commission, *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Shaping Europe's Digital Future*, 19.2.2020, COM(2020) 67 final, p. 11 f.
[21] European Commission, *Communication from the Commission to the European Parliament and the Council. 2022 Strategic Foresight Report. Twinning the green and digital transitions in the new geopolitical context*, 29.6.2022, COM(2022) 289 final.
[22] Additionally, on 30 September 2025, the President of the European Commission, Ursula von der Leyen, announced that the EU would set new climate targets ahead of the COP30 summit, which took place in Belém in November 2025. The updated package aimed to strengthen the implementation of the EGD, with particular focus on reducing carbon dioxide emissions by 2040, promoting investment in renewable energy, enhancing energy efficiency, and developing a circular economy, thereby reconciling economic growth with environmental sustainability.
[23] European Commission, *The European Green Deal*, cit., p. 9.

particularly AI, «will not only accelerate circularity but also the dematerialization of our economy and make Europe less dependent on primary materials»[24].

Additionally, the Special Committee on Artificial Intelligence in a Digital Age (AIDA), a study commission established by the European Parliament during the 18 June 2020 plenary session with a 12-month mandate, confirmed the role of AI in its *Working Paper on Artificial Intelligence and the Green Deal*, asserting that AI systems are key tools for implementing the EGD, as they help to reinforce and facilitate the achievement of climate neutrality and the drastic reduction of harmful emissions[25].

Moving on to some of the EGD's concrete implementation measures concerning AI systems, the *European Climate Law*[26] must first be mentioned, that translated the EU's climate neutrality target by 2050 into a binding regulation. A reference to AI can be found in Article 3(3) of the regulation, which mentions the «best available and most recent scientific evidence» as a guiding principle for the European Scientific Advisory Board on Climate Change, an independent body that reviews and evaluates EU policies on the green transition to ensure their alignment with climate goals. The provision further strengthens the view of technological progress as a tool to mitigate the effects of environmental issues.

In terms of environmental sustainability, other implementing measures of the Green Deal include Regulation (EU) 2024/1991 on nature restoration[27] and Regulation (EU) 2024/1252 on critical raw materials[28]. While the EU's intention in the first case was to halt the degradation of ecosystems to rebuild them, some critical issues arise from the fact that, in this regulation, AI is mentioned only as a tool for monitoring the objectives set out therein (Article 20). As for the regulation on critical raw materials, although its aim is to ensure a more circular and sustainable supply of raw materials, it establishes a sustainability certification system involving certifying bodies and environmental standards that are often inadequate to protect local resources, especially in non-EU countries where most of the extraction activities take place[29].

Complementing these measures, Directive 2023/1791 on energy efficiency includes specific measures for data centers, recognizing their high energy consumption and environmental impact. These measures aim to promote energy-efficient technologies and monitor energy consumption, yet their actual effectiveness remains uncertain. The Directive prescribes reporting obligations and indicators for energy consumption, but implementation may vary

[24] European Commission, *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. A New Circular Economy Action Plan. For a cleaner and more competitive Europe*, 11.3.2020, COM(2020) 98 final, p. 2.

[25] Special Committee on Artificial Intelligence in a Digital Age (AIDA), *AIDA Working Paper on Artificial Intelligence and the Green Deal*, March 2021, p. 2 ff.

[26] Regulation (EU) 2021/1119 of the European Parliament and of the Council of 30 June 2021 establishing the framework for achieving climate neutrality and amending Regulations (EC) No 401/2009 and (EU) 2018/1999 (*European Climate Law*).

[27] Regulation (EU) 2024/1991 of the European Parliament and of the Council of 24 June 2024 on nature restoration and amending Regulation (EU) 2022/869.

[28] Regulation (EU) 2024/1252 of the European Parliament and of the Council of 11 April 2024 establishing a framework for ensuring a secure and sustainable supply of critical raw materials and amending Regulations (EU) No 168/2013, (EU) 2018/858, (EU) 2018/1724 and (EU) 2019/1020.

[29] On the critical issues of the regulation on critical raw materials, see also C. Di Francesco Maesa, *Economia circolare e IA*, cit., p. 20 ff.

significantly across Member States, and, pursuant to Article 12, the current rules apply only to data centers above certain thresholds, excluding much of the on-site enterprise infrastructure. Furthermore, while systematic data collection could inform the development of sustainability indicators, greater coordination and support from national and regional authorities, involving sustainable energy agencies, would be pivotal for ensuring consistent application and promoting energy efficiency, as indicated in Recitals 38 and 39[30].
Finally, regarding electronic waste, another implementing act of the EGD worth mentioning is Regulation (EU) 2024/1157 on waste shipments[31], which mainly aims to monitor waste shipments within and outside the EU to prevent illegal disposal and environmental harm. However, despite the commendable intentions of the EU, the framework established by this regulation continues to clash with the persistent problem of illegal waste trade. According to recent data, between 15% and 30% of waste shipments are illegal: as a result, these shipments escape proper monitoring and carry a higher risk of improper disposal or treatment, thereby increasing their potential negative impact on the environment[32].

IV.1 *The Corporate Digital Responsibility*.

The deployment of AI technologies raises important questions about responsibility, notably with respect to their negative environmental impacts and who should bear accountability for these consequences. One possible answer is that responsibility should lie with those involved in the production or use of AI services, such as AI developers, tech workers, AI companies and governments, who should be transparent with the public on the emissions from training and deploying AI models. That said, it is also true that AI is used by consumers, who do not easily fit into this regulatory scheme, as unlike companies that develop and use AI services for profit, consumers act for non-commercial purposes.
While no clear answers have yet emerged, there have been some EU initiatives on corporate responsibility based on the principles of Article 191(2) TFEU, including the precautionary principle, preventive action, rectification at source, and the polluter-pays principle, which requires that those responsible for environmental damage bear the cost of environmental restoration[33].

[30] Directive (EU) 2023/1791 of the European Parliament and of the Council of 13 September 2023 on energy efficiency and amending Regulation (EU) 2023/955 (recast).
[31] Regulation (EU) 2024/1157 of the European Parliament and of the Council of 11 April 2024 on shipments of waste, amending Regulations (EU) No 1257/2013 and (EU) 2020/1056 and repealing Regulation (EC) No 1013/2006 (*Waste Shipments Regulation*).
[32] C. Di Francesco Maesa, *Economia circolare e IA*, cit., p. 23 ff.
[33] For a detailed examination of the principles laid down in Article 191(2) TFEU, see S. Amadeo, *Art. 191 TFUE*, cit., p. 1622 ff.; P. A. Pillitu, *Art. 191 TFUE*, cit., p. 1109 ff. On Corporate Digital Responsibility see, *ex plurimis*, K. Crawford, *Atlas of AI*, cit., p. 41 ff.; M. C. Gaeta, *Intelligenza artificiale sostenibile*, cit., p. 155 ff.; C. J. Herden, E. Alliu, A. Cakici et al., *Corporate Digital Responsibility*, available at https://doi.org/10.1007/s00550-020-00509-x (last visited Jul. 24, 2025); L. Lobschat, B. Mueller, F. Eggers et al., *Corporate digital responsibility*, available at https://doi.org/10.1016/j.jbusres.2019.10.006 (last visited Jul. 24, 2025); A. Nordgren, *Artificial intelligence and climate change*, cit., p. 10; G. Schneider, *Le tecnologie societarie alla prova del governo sostenibile tra ESG, diligenza d'impresa e corporate digital responsibility*, available at

First and foremost, the *Corporate Sustainability Reporting Directive* (hereinafter CSRD) [34] introduces new sustainability reporting obligations for European companies, requiring them to issue a sustainability report based on ESG factors (Environmental, Social, and Governance), aimed at providing the public with information on the impact these companies have on the environment, and thus on a fundamental right. In practical terms, Corporate Digital Responsibility, through ESG reporting, considers several indicators under the Environmental factor, such as energy efficiency, greenhouse gas emission reduction, circular economy practices, management of e-waste, and the development of sustainable software. These indicators allow for an evaluation of the environmental impact arising from the production or use of AI systems by companies, as they cover the entire lifecycle of hardware, from production and operation to disposal and recycling of ICT devices and infrastructures[35]. Another key directive is the *Corporate Sustainability Due Diligence Directive* (CSDDD)[36], designed to make European companies more accountable for human rights violations and environmental harm across most phases of the AI systems' lifecycle, from production to distribution, transport, and storage of a product or the provision of a service. However, a limitation of the CSDDD lies in its focus on the earlier stages of a product's lifecycle: it does not require companies to assess the potential negative human rights or environmental impacts arising from the actual use of products and services that include AI systems and yet most harmful consequences linked to AI systems stem from their use (Article 3(1)(g))[37].

V. THE AI ACT AND THE ENVIRONMENTAL PROTECTION

The application of AI technologies in the European Union is regulated by Regulation (EU) 2024/1689 (*Artificial Intelligence Act*, hereinafter the AI Act) [38], which represents the

https://www.rivistacorporategovernance.it/Article/Archive/index_html?ida=85&idn=10&idi=-1&idu=-1 (last visited Jul. 24, 2025).

[34] Directive (EU) 2022/2464 of the European Parliament and of the Council of 14 December 2022 amending Regulation (EU) No 537/2014, Directive 2004/109/EC, Directive 2006/43/EC and Directive 2013/34/EU, as regards corporate sustainability reporting (*Corporate Sustainability Reporting Directive*).

[35] Together with the Social and Governance factors, various aspects are taken into account, respectively, such as the social impact deriving from the use of digital products, like working conditions within the company, and all matters related to the company's management practices. For further insight into ESG factors and their inclusion in corporate sustainability reporting, see M. C. Gaeta, *Intelligenza artificiale sostenibile*, cit., p. 151 ff.

[36] Directive (EU) 2024/1760 of the European Parliament and of the Council of 13 June 2024 on corporate sustainability due diligence and amending Directive (EU) 2019/1937 and Regulation (EU) 2023/2859.

[37] C. Di Francesco Maesa, *Economia circolare e IA*, cit., p. 23 ff.

[38] Regulation (EU) 2024/1689 of the European Parliament and of the Council of 13 June 2024 laying down harmonized rules on artificial intelligence and amending Regulations (EC) No 300/2008, (EU) No 167/2013, (EU) No 168/2013, (EU) 2018/858, (EU) 2018/1139 and (EU) 2019/2144 and Directives 2014/90/EU, (EU) 2016/797 and (EU) 2020/1828 (*Artificial Intelligence Act*). For a legal perspective on the AI Act see M. Carta, *Il Regolamento UE sull'Intelligenza Artificiale: alcune questioni aperte*, available at https://rivista.eurojus.it/il-regolamento-ue-sullintelligenza-artificiale-alcune-questioni-aperte/ (last visited Jul. 24, 2025); E. Cirone, *L'AI Act e l'obiettivo (mancato?) di promuovere uno standard globale per la tutela dei diritti fondamentali*, available at https://www.aisdue.eu/wp-content/uploads/2024/06/Post-Enza-Cirone.pdf (last visited Jul. 24, 2025); M. Inglese, *Il regolamento sull'intelligenza artificiale come atto per il completamento e il buon funzionamento del mercato interno?*, available at https://www.aisdue.eu/wp-content/uploads/2024/06/Post-Marco-Inglese.pdf (last visited Jul. 24, 2025); A. Volpato, *Il ruolo delle norme armonizzate nell'attuazione del regolamento sull'intelligenza artificiale*, available at https://www.aisdue.eu/wp-content/uploads/2024/06/Post-Annalisa-Volpato.pdf (last visited Jul. 24, 2025).

culmination of a series of initiatives supporting the development of trustworthy AI and aims to ensure both the safety of AI technologies and the protection of fundamental rights[39].
The EU Treaties contain no explicit provisions regarding environmental protection in connection with AI systems. However, among the general clauses that have served as the basis for regulatory action, we can mention Article 7 of the TFEU, which ensures coherence between the Union's policies, actions, and objectives while also affirming the principle of conferral of competences, and Article 11 of the TFEU, which provides for the integration of environmental protection into the Union's policies and actions, aligning with the principles set out in Article 37 of the Charter of Fundamental Rights[40].
Among the various steps that led to the adoption of the AI Act, the 2020 *White Paper on AI* initially stressed the importance of harnessing AI in support of the EGD and the fight against climate change, highlighting AI's potential to optimize resource use and energy consumption, and to guide environmentally positive choices. Nevertheless, it did not address the environmental impact caused by AI technologies themselves[41]. This aspect was instead considered in other contemporaneous documents, such as the 2019 *Ethics Guidelines for Trustworthy AI*, which identified respect for social and environmental well-being as a key requirement for making AI systems trustworthy. In this document, it is stated that AI systems should meet environmental sustainability standards throughout the entire supply chain, from design to final use by, for example, assessing resource use and energy consumption during the training phase, to enable the selection of less environmentally harmful options[42].
This path eventually led to the AI Act, which entered into force on August 1, 2024, as the world's first legally binding act governing the development, deployment and placing on the market of AI technologies. In its implementation, the AI Act is accompanied by the recent *AI Continent Action Plan*, a communication from the European Commission dated April 9, 2025, which outlines the next steps in the EU's AI strategy to become «a leading AI Continent». The Plan focuses on: (i) developing large-scale computing infrastructure, called AI Factories and Gigafactories, designed to promote scientific collaboration between researchers, entrepreneurs, and investors; (ii) improving access to high-quality data for AI innovators through targeted initiatives; (iii) advancing AI algorithm development and

[39] European Commission, *Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions. Coordinated Plan on Artificial Intelligence*, 7.12.2018, COM(2018) 795 final; European Commission, *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on boosting startups and innovation in trustworthy artificial intelligence*, 24.1.2024, COM(2024) 28 final. On the risk-based approach adopted in the AI Act for the assessment of AI systems, see V. D'Antino, *L'approccio basato sul rischio nell'AI Act: un nuovo paradigma di regolazione dell'intelligenza artificiale*, available at https://www.federalismi.it/nv14/articolo-documento.cfm?artid=52349 (last visited Jul. 24, 2025), p. 18 ff.
[40] For leading scholarly commentaries on the aforementioned articles, see S. Amadeo, *Art. 11 TFUE*, cit., p. 407-414; M. C. Baruffi, *Art. 7 TFUE*, in F. Pocar, M. C. Baruffi (a cura di), *Commentario breve ai Trattati dell'Unione europea*, p. 170-172 (2nd ed., CEDAM, Padova, 2014); M. Onida, *Art. 37 Carta*, cit., p. 691-707; P. A. Pillitu, *Art. 11 TFUE*, cit., p. 173-175; P. A. Pillitu, *Art. 37 Carta*, *ibid.*, p. 1752.
[41] European Commission, *White Paper on Artificial Intelligence - A European Approach To Excellence And Trust*, 19.2.2020, COM(2020) 65 final, p. 1 ff.
[42] Independent High Level Expert Group on Artificial Intelligence, *Ethics Guidelines for Trustworthy AI*, available at https://data.europa.eu/doi/10.2759/346720 (last visited Jul. 24, 2025).

promoting their adoption in strategic sectors to support industrial and scientific applications, public services, and uptake by SMEs, mid-sized enterprises, and public administrations; (iv) enhancing AI skills and literacy, promoting diversity, supporting education and research, and attracting and retaining talent from within and outside the EU; (v) leveraging the EU's single market, supported by the AI Act, to reinforce trust and security in AI while reducing fragmentation, with measures to ease compliance, particularly for smaller innovators[43].

However, the inadequacy of the AI Act in balancing environmental protection and technological development diverges from the intentions expressed in the preparatory documents preceding its adoption, which appeared to place greater emphasis on integrating digitalization within a green framework. As regards environmental protection in relation to AI systems, the references contained in the AI Act appear limited and insufficient to address the scale of environmental challenges and to ensure the ecological sustainability of such systems, as would be desirable[44].

In this respect, in Article 1(1) of the Regulation, environmental protection is merely mentioned in passing, stating that: «The purpose of this Regulation is to improve the functioning of the internal market and promote the uptake of human-centric and trustworthy artificial intelligence (AI), while ensuring a high level of protection of health, safety, fundamental rights enshrined in the Charter, including democracy, the rule of law and environmental protection, against the harmful effects of AI systems in the Union and supporting innovation».

Subsequently, Article 3(49)(d) sets an obligation for providers of general-purpose AI models to document the known or estimated energy consumption of the model, while providers of high-risk AI systems are required to report direct or indirect environmental harm and to consider such harm as serious incidents.

Environmental considerations are further reflected in Article 40(2), which foresees the development of standards «to improve AI systems' resource performance, such as reducing the high-risk AI system's consumption of energy and of other resources during its lifecycle, and on the energy-efficient development of general-purpose AI models».

A related concern arises from the use of general-purpose AI models with systemic risks, which, as provided in Articles 53(1)(a) and 112(6), may be subject to specific reporting obligations imposed by the Commission. These obligations, as set out in Annex XI, Section 1, aim to produce adequately measured and comparable information on the known or estimated energy consumption of the model. Yet, such reporting obligations only apply to the energy used during the development phase of the model and not during inference, meaning the actual use of the model is not considered. From this perspective, the use of AI systems, which involves processing inputs and data fed into the model to generate predictions or outputs, entails a significantly higher energy consumption than that required during their development.

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[43] European Commission, *Proposal for a Regulation*, cit.; *Id.*, *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. AI Continent Action Plan*, 9.4.2025, COM(2025) 165 final.

[44] P. Hacker, *Sustainable AI Regulation*, available at https://ssrn.com/abstract=4467684 (last visited Jan. 26, 2026), p. 20 f.

In addition to this, the provisions focus solely on the issue of energy consumption, without addressing other significant environmental impacts caused by AI that have already been highlighted, such as excessive water usage, pollution, and the high consumption of energy and water associated with the extraction of critical raw materials, or the lack of effective mechanisms to ensure the disposal of electronic waste[45].

Continuing through the provisions of the AI Act, Article 95(2)(b), echoing Recital 165, states that the European AI Office and Member States shall promote the drafting of codes of conduct for AI systems aimed at encouraging voluntary adherence to certain standards. These standards should include parameters such as the assessment and minimization of the environmental impact of AI systems as indicators of progress towards specific objectives. Nonetheless, the adoption of such codes of conduct is purely voluntary, meaning that they do not impose binding legal obligations on AI providers and deployers, who are more likely, in their economic activities, to prioritize profit over environmental concerns. For these reasons, the codes of conduct under Article 95 have been deemed inadequate for establishing coercive mechanisms that ensure their implementation[46].

Finally, Article 112(10) of the AI Act requires that the Commission may, where appropriate, submit proposals to amend the Regulation, considering several factors, including the impact of AI systems on health, safety, and fundamental rights, but without explicitly mentioning the environment. As can be observed, potential amendments to the Regulation aimed at protecting environmental sustainability could only be proposed by the Commission through an interpretation of this provision that includes environmental protection among the fundamental rights covered by the Fundamental Rights Impact Assessment (FRIA) of the regulation, a point that remains controversial in doctrine[47].

VI. Concluding remarks: AI environmental challenges, opportunities, and possible solutions

As has been repeatedly emphasized, the use of AI is inherently ambivalent: while it can exacerbate challenges such as climate change, it also holds significant potential to advance the EU's environmental sustainability objectives. Some studies indicate that, in certain contexts, AI and ICT more broadly may generate environmental benefits that surpass their associated costs, highlighting the need to carefully consider and harness these positive applications, a few of which are discussed below.

To begin with, AI can help inform public decision-makers and private actors – including companies and individuals – about environmentally sustainable business practices and

45 In this sense, N. Alder, K. Ebert, R. Herbrich, P. Hacker, *AI, Climate, and Regulation: From Data Centers to the AI Act,* available at https://doi.org/10.48550/arXiv.2410.06681 (last visited Jul. 24, 2025), p. 3 ff.; C. Di Francesco Maesa, *Economia circolare e IA*, cit., p. 15 ff.; C. J. Wu, R. Raghavendra, U. Gupta et al., *Sustainable AI: Environmental Implications, Challenges and Opportunities*, available at https://doi.org/10.48550/arXiv.2111.00364 (last visited Jul. 24, 2025), p. 1 ff.

46 These critical issues have been highlighted by C. Di Francesco Maesa, *Economia circolare e IA*, cit., p. 15 ff.

47 For an overview of the scholarly debate on the inclusion of the right to a healthy environment among the fundamental rights protected by the Charter, see M. Onida, *Art. 37 Carta*, cit., p. 692 ff.

consumption habits, thereby guiding economic decisions and lifestyles toward greater responsibility, ethics, and sustainability. This role of AI would also further promote the economic paradigm of the circular economy across society, as AI could support the design of circular products, components, and materials, with more resilient and durable designs, ranging from urban buildings, bridges and infrastructure to consumer goods[48].

Still on the topic of circularity, the *European Parliament Resolution of 3 May 2022 on Artificial Intelligence in a Digital Age* states that AI systems have «the potential to benefit security of supply, especially in the operation, monitoring, maintenance and control of water, gas and electricity networks», thus helping to implement several of the European Union's circular economy principles, including ethical sourcing of raw materials, recycling of materials and waste reduction[49]. In addition, the resolution highlights that AI, in the energy sector, particularly through big data analytics, «can monitor, optimize and reduce energy consumption and production, as well as support the integration of renewable energies into existing electricity grids»[50].

Another significant function of AI is its predictive capability, which could process vast amounts of data to create environmental monitoring systems, tracking indicators such as temperature and carbon dioxide levels. This would enable more sustainable and rational management of resources, contribute to reducing greenhouse gas emissions, and provide a comprehensive overview of the climate situation to safeguard biodiversity, ecosystems, and forests[51]. Moreover, AI could assist in forecasting extreme weather events, such as storms, hurricanes, droughts, or flooding, mitigating their impacts and supporting planning in economic sectors like agriculture[52].

Nonetheless, the positive potential of AI must be balanced against its environmental impacts. As the data discussed above demonstrate, these impacts continue to aggravate ecological challenges as well as economic and social inequalities globally, particularly in less developed

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[48] For further insight on these topics, see C. A. Ciaralli, *Intelligenza artificiale*, cit., p. 54; A. Nordgren, *Artificial intelligence and climate change*, cit., p. 5 f.; D. Rolnick, P. L. Donti, L. H. Kaack, *Tackling Climate Change with Machine Learning*, available at https://doi.org/10.48550/arXiv.1906.05433 (last visited Jul. 24, 2025); D. G. Victor, *How artificial intelligence will affect the future of energy and climate*, available at https://www.brookings.edu/articles/how-artificial-intelligence-will-affect-the-future-of-energy-and-climate/ (last visited Jul. 24, 2025).

[49] European Parliament, *European Parliament Resolution of 3 May 2022 on Artificial Intelligence in a Digital Age (2020/2266(INI))*, 6.12.2022, 2022/C 465/06, par. 41.

[50] European Parliament, *European Parliament Resolution*, cit., par. 40.

[51] For a more detailed analysis of these aspects, see. Aa. Vv., *The role of Artificial Intelligence in the European Green Deal* (study requested by the AIDA Committee), 16 ff. (Luxembourg, 2021); F. Camisa, *Ambiente e tecnologia*, cit., p. 68 f.; M. C. Gaeta, *Intelligenza artificiale sostenibile*, cit., p. 148 f.; A. Nordgren, *Artificial intelligence and climate change*, cit., p. 11; A. L. Stein, *Artificial Intelligence and Climate Change*, cit., p. 893 ff.; A. van Wynsberghe, *Sustainable AI*, cit.; S. Yadav, A. Samadhiya, A. Kumar, *Achieving the sustainable development goals through net zero emissions: innovation-driven strategies for transitioning from incremental to radical lean, green and digital technologies*, in *Resources, Conservation and Recycling*, available at https://doi.org/10.1016/j.resconrec.2023.107094 (last visited Jul. 24, 2025).

[52] On these topics see J. Cowls, A. Tsamados, M. Taddeo, L. Floridi, *The AI gambit*, cit., p. 284 ff.; C. Di Francesco Maesa, *Economia circolare e IA*, cit., p. 5 ff.; A. Naji Khallaf, N. Moneer Alqerafi, *Using AI to Help Reduce the Effect of Global Warming*, available at https://powertechjournal.com/index.php/journal/article/view/464 (last visited Jul. 24, 2025); A. Nordgren, *Artificial intelligence and climate change*, cit., p. 5 f.; D. Rolnick, P. L. Donti, L. H. Kaack, *Tackling Climate Change*, cit.

countries[53]. In view of these challenges and opportunities, this research now turns to the question of which solutions can promote what has been defined as an ethical, responsible, and sustainable use of AI[54].

In general, it is desirable for the European Union to strike a better balance between the objectives linked to the twin transitions by introducing more specific and binding regulations on the environmental impacts of digitalization and, more precisely, of AI. Indeed, rather than relying solely on transparency-based obligations, such as the disclosure of energy consumption or greenhouse gas emissions, a broader set of regulatory instruments at the EU level appears indispensable to effectively integrate environmental sustainability into AI governance[55].

Beyond this, a more nuanced and forward-looking approach could be envisaged, combining preventive forms of co-regulation and shared responsibility between public authorities, AI providers and deployers, intended to steer technological development towards environmentally sustainable outcomes before environmental harm materializes, covering, for example, product design and practices in supply chain management[56].

Thereafter, and as a complementary measure, another possible solution could consist of imposing penalties on those who use AI in ways that negatively affect the environment, such as causing pollution and other such harms, in line with the polluter-pays principle. However, the punitive approach appears to conflict with the fact that companies, within the EU's legal framework, are encouraged to adopt AI, and this raises the question of why they should be held accountable for the consequences of using a technology they are incentivized to implement.

Furthermore, there remains the issue of proving environmental harm, which is not easily achieved, particularly when such harm affects distant and developing countries[57]. Since one of the proposed solutions entails the imposition of penalties on actors whose use of AI causes environmental harm, the effectiveness of such an approach depends on the availability of reliable, transparent and comparable metrics capable of quantifying that harm. Nevertheless, at present, the environmental footprint of AI remains difficult to assess in a comprehensive manner; for instance, the indicators set out in Annex XI, Section 1 of the AI Act – applicable to AI models with systemic risks – focus primarily on energy consumption limited to the training phase, while overlooking other relevant impacts such as water use, raw material extraction, and electronic waste. This narrow focus risks underestimating the overall environmental costs of AI systems, particularly in the case of large-scale generative models, especially where such models qualify as AI models with systemic risks under the AI Act, as

53 On the economic and social inequalities that the ICT sector produces, see C. A. Ciaralli, *Intelligenza artificiale*, cit., p. 77 ff.; M. C. Gaeta, *Intelligenza artificiale sostenibile*, cit., p. 148 ff.; A. Nordgren, *Artificial intelligence and climate change*, cit., p. 9 ff.

54 F. Camisa, *Ambiente e tecnologia*, cit., p. 60 ff.; A. Nordgren, *Artificial intelligence and climate change*, cit., p. 4 ff.

55 P. Hacker, *Sustainable AI Regulation*, cit., p. 8 ff.

56 P. Hacker, *Sustainable AI Regulation*, *ibid.*, p. 22 f.

57 On the responsibility for environmental damage borne by high-income countries, see H. Sue, *Global Environment and International Inequality*, in S. Gardiner, S. Caney, D. Jamieson, H. Sue (eds.), *Climate Ethics: Essential Readings*, 101-111 (Oxford University Press, Oxford, 2010).

their deployment and repeated retraining entail significant and continuous resource consumption.

A possible way forward could therefore lie in the development of standardized, life-cycle-based assessment framework relying on composite indicators capable of capturing the overall environmental impact of AI systems beyond their development phase[58]. While such metrics may not allow for a perfectly accurate quantification of damage, they could nonetheless provide a solid basis for attributing environmental responsibility to actors exercising effective control over AI systems. This, in turn, could strengthen the enforceability of sanctioning mechanisms, including fines, corrective actions, compliance orders, temporary or permanent suspension of market placement or service, and, where appropriate, withdrawal of AI systems.

In light of the findings of this research, emphasis must be placed on the importance of ensuring the development of Sustainable AI, namely an AI that is fully compatible with the green transition. Against this backdrop, high-impact AI systems could be progressively integrated into existing environmental policy instruments, such as regulatory frameworks that set binding environmental standards and incentives that promote the development of greener technologies, thereby internalizing their ecological externalities and fostering technological innovation in support of broader sustainability objectives.

Within the EU framework, this approach would present institutions and Member States with the challenging task of carefully balancing the green and digital transitions, while simultaneously addressing the complex ethical and social questions raised by AI. By pursuing such a strategy, AI could be harnessed ethically, responsibly, and in alignment with the environmental sustainability goals promoted by the EU, ultimately serving as a tool to support both governance structures and society in confronting the increasingly urgent environmental challenges of our time[59].

[58] P. Hacker, *Sustainable AI Regulation*, cit., p. 23 f.

[59] European Parliament, *European Parliament Resolution*, cit., parr. 37-45 specifically dedicated to the relationship between AI and the EDG.