# Green Algorithms: Environmental Impact, Legal and Ethical Framework in Artificial Intelligence

Vera Iglesias Losada

Faculty of Law, Universidade da Coruña, Centro de Investigación en Tecnologías de la Información y las Comunicaciones
Correspondence: vera.losada@udc.es

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*Abstract*: This article explores the concept of green algorithms and their connection to sustainability in the field of artificial intelligence, analyzing the environmental impact of emerging technologies, with special attention to the energy consumption of AI models and the carbon footprint generated by data centers. The aim is to delve into the legal and ethical aspects related to the development of sustainable technologies, reviewing the international and European regulatory framework, as well as the existing legal gaps, while addressing the ethical principles that should guide responsible technological innovation.

## 1 Introduction

In the most recent phase of the digital era, artificial intelligence (AI) and the algorithms that underpin it are playing a transformative role across multiple sectors, both public and private, from healthcare to finance. According to Huarte (2023), AI is gradually beginning to shed its exceptional status, with what once seemed futuristic becoming something present, tangible, and real.

However, the rapid growth of these technologies poses serious environmental challenges, particularly in terms of energy consumption and the use of natural resources. Large Language Models (LLMs) require vast amounts of energy, water, and minerals for their training and operation. According to the research by Luccioni et al. (2024), a single query to a model such as ChatGPT can consume between six and ten times more energy than a conventional web search. In addition, the GPT-3 model can use approximately 500 ml of water for every 10 to 50 queries, depending on the location and efficiency of the data center. This water consumption is mainly due to the cooling systems required to keep data center servers operational.

These figures highlight the urgent need for a transition towards so-called green algorithms, which represent not only a technical improvement but also an ethical and environmental imperative. In response to this paradigm, researchers developed a solution based on modifying the algorithms underpinning AI to make them more sustainable, what we now refer to as "green algorithms". The notion of green algorithm involves integrating the environmental variable into the source code, and, as Huarte (2023) defines them, they are capable of maximising energy efficiency and reducing the environmental impact of AI models, while simultaneously supporting the use of this technology to address various environmental challenges. Unlike traditional algorithms, these aim to optimise the use of computational resources, reduce energy consumption, and minimise the environmental impact of AI without compromising its performance.

## 2 Sustainability in Artificial Intelligence: Green in AI and Green by AI

Artificial intelligence has great potential to help reduce its own environmental impact, playing a key role in lowering greenhouse gas emissions and improving efficiency in sectors such as energy production and consumption, agriculture, land use, biodiversity management, communications, and transport, as highlighted in the research by Bolón-Canedo et al. (2024). Given that the environmental impact of this disruptive technology is growing exponentially, serious concerns about its carbon footprint have led to a new paradigm: Green AI. Alzoubi and Mishra (2024) define green artificial intelligence as the application of AI technology with an emphasis on energy consumption, CO2 emissions reduction, and environmental sustainability.

At this point, having outlined the general notions, it is worth exploring the difference between the concepts of Green in AI and Green by AI, which, although closely related—both falling under the broader term Green AI—suggest an important distinction for the purposes of this study. On the one hand, the concept of Green by AI refers to the use of artificial intelligence as a tool to achieve environmental objectives; these are algorithms specifically trained and employed to address environmental challenges. On the other hand, Green in AI, or green algorithms by design, refers to those that are energy-efficient both during their training and use. Green in AI focuses on developing AI algorithms and models that consume fewer resources, for example, by reducing energy consumption when using a chatbot.

## 3 Innovation and Sustainability: An Ethical Balance

Innovation and sustainability are not incompatible concepts, but they do maintain a dynamic tension that demands constant balance. This duality, as highlighted by Rodríguez (2022), underscores the importance of advancing towards sustainable artificial intelligence, capable of responding to the rapid pace of technological evolvement without losing sight of the evolving moral sensitivity required by ecological ethics.

The UNESCO Recommendation on the Ethics of Artificial Intelligence (2021)[1] establishes a foundation that reinforces this integrative vision. It acknowledges that AI technologies can be beneficial for the environment, but warns that their development must be guided by ethical principles, respect for human rights, and consideration of associated risks. Far from hindering innovation, this approach seeks to promote responsible research that generates long-term social and environmental value.

> «AI technologies have the potential to be beneficial to the environment and ecosystems [...], however, taking into account risks and ethical concerns should not hamper innovation and development but rather provide new opportunities and stimulate ethically-conducted research and innovation that anchor AI technologies in human rights and fundamental freedoms, values and principles, and moral and ethical reflection». UNESCO (2021)

The relationship between innovation and sustainability should not be understood as a dichotomy, but as a tension that demands balance, reflection, and responsibility. Artificial intelligence must be developed under ethical principles that ensure its positive contribution to the environment and to society. Integrating sustainability as an ethical criterion does not mean slowing progress, but rather guiding it towards goals that respect the planet's ecological limits and promote truly sustainable development.

[1] Recommendation adopted by the General Conference of UNESCO at its 41st session, held in Paris from 9 to 24 November 2021.

## 4 International and European Regulatory Framework on Digital Sustainability

Since the second half of the 2010s, numerous processes have promoted dialogue and international cooperation to explore the potential of artificial intelligence in achieving the Sustainable Development Goals (SDGs). In this context, the first intergovernmental standards on artificial intelligence were developed and agreed upon by the Member States of the Organisation for Economic Co-operation and Development (OECD) in May 2019. This resulted in the adoption of the OECD Recommendation on AI, which, among other aspects, left a trace on the environmental sphere:

> «Stakeholders should proactively engage in responsible stewardship of trustworthy AI in pursuit of beneficial outcomes for people and the planet, such as [...] protecting natural environments, thus invigorating inclusive growth, well-being, sustainable development and environmental sustainability ». OECD (2019)

In the European context, Article 11 of the Treaty on the Functioning of the European Union (TFEU) offers a general approach that reflects the spirit of European policies by stating that environmental protection requirements must be integrated into the definition and implementation of the Union's policies and activities, in particular with a view to promoting sustainable development. Additionally, Article 191 TFEU sets out the EU's environmental policy, pursuing objectives such as the preservation, protection, and improvement of the environment, as well as the prudent use of natural resources. In this way, the TFEU provides a solid foundation for EU environmental legislation, enabling the adoption of harmonized measures and emphasizing the importance of international cooperation between Member States and third countries or competent international organizations.

Furthermore, regulatory action is necessary in order, in the words of Gailhofer et al. (2021), to align AI with the goals set out in the European Green Deal (EGD), which aims to promote more sustainable economic prosperity for Europe. The EGD is defined as the EU's growth strategy, established in 2019, it consists of a package of policy initiatives that set the EU on a path toward a green transition, with the ultimate goal of achieving climate neutrality by 2050" [2]. Regarding specific regulation on artificial intelligence, Regulation (EU) 2024/1689 of the European Parliament and of the Council of 13 June 2024, laying down harmonized rules on Artificial Intelligence, represents a regulatory milestone. Article 1 of the regulation states that its purpose is to promote human-centric and trustworthy AI, ensuring a high level of protection for health, safety, fundamental rights, and the environment. This regulation reflects the intention to align technological development with the principles of the EGD and the EU's climate commitments.

On the international stage, China has emerged as a major player and has created systems to manage the development and use of technology. Additionally, Canada has developed initiatives to promote the ethical growth of AI and address relevant ethical concerns in the field, creating the Artificial Intelligence and Data Act (AIDA) [3], which promotes the ethical development of AI and addresses concerns related to ethics and sustainability. At the same time, Australia aims to ensure that AI technologies are developed ethically, fostering public trust in technology through the use of a National AI Ethics Framework. The analysis of international and European initiatives around artificial intelligence and sustainability reveals a process of regulatory and policy maturation that has evolved from general approaches to specific frameworks for action. The growing concern regarding the environmental impact of emerging technologies has driven

[2] European Green Deal, Council of the European Union, available at: https://www.consilium.europa.eu/en/policies/european-green-deal/

[3] Artificial Intelligence and Data Act (AIDA), available at: The Artificial Intelligence and Data Act (AIDA) – Companion document

the formulation of standards, recommendations, and regulations that seek to align AI development with the principles of sustainable development. Ultimately, the challenge lies not only in regulating AI, but in doing so in a way that promotes responsible innovation, capable of addressing today's environmental challenges without compromising the rights and well-being of future generations (inter-generational solidarity).

## 5 Analysis of European Directives and the Artificial Intelligence Regulation in the Field of Sustainability

Researchers such as Betanzos and Canedo (2020) have concluded that the expansion of AI systems across various sectors is not only driving significant economic transformations but also posing major social challenges that demand an appropriate legislative response. In this context, the European Union has adopted several directives aimed at integrating sustainability into business activities.

Directive (EU) 2022/2464, known as the Corporate Sustainability Reporting Directive (CSRD), was adopted on December 14, 2022. Its main objective is to enhance transparency and corporate accountability on environmental issues. To achieve this, the directive introduces the European Sustainability Reporting Standards, which set specific criteria for drafting environmental care reports. This regulation seeks to promote corporate sustainability in private entities by integrating principles that help mitigate environmental risks and encouraging ethical use of technology without hindering innovation.

In this line, Directive (EU) 2024/1760 on corporate sustainability due diligence reinforces this approach. It requires private entities to identify the negative impacts of their activities on the environment and human rights, so they can prevent, mitigate, or eliminate them entirely.

In July 2024, the European Union adopted Regulation (EU) 2024/1689 on Artificial Intelligence. This regulation aims to ensure that AI systems developed and used within the EU are safe, ethical, and fully compliant with fundamental rights. Although it does not focus specifically on environmental issues, it classifies AI systems by risk level and prohibits those deemed unacceptable under European ethical principles. It also emphasizes environmental protection as a core value, aligning technological development with sustainability goals.

Doctrine has sparked a debate on whether the energy efficiency of everything involved in AI tools could be regulated by Directive 2009/125 of October 21, which establishes a framework for setting eco-design requirements applicable to energy-related products, transposed into Spanish law through *Real Decreto 187/2011*, concerning the establishment of eco-design requirements for energy-related products. If that would be the case, it would not be necessary to independently regulate the ecological impact of AI, despite the fact that including AI systems within the scope of this regulation has proven controversial and questionable. This opens the door to a broader debate on the need to develop a specific regulatory framework that considers the technical, operational, and environmental particularities of AI systems, thereby ensuring effective regulation aligned with the European Union's sustainability goals.

Both European sustainability directives and the AI Act establish a robust regulatory framework that guides the development of responsible technologies. The study of European regulations reveals a progressive and structured effort to integrate sustainability into the development and implementation of AI-based technologies, setting guiding principles to mitigate the environmental impacts of technological activity. In this regard, space is open for reflection and the

design of a specific regulatory framework that considers the technical, operational, and environmental particularities of artificial intelligence. Such regulation should be flexible enough to adapt to rapid technological evolution, yet solid enough to ensure legal certainty and coherence with the principles of sustainable development. However, the current challenge is not only regulatory but also strategic: it is about ensuring that regulation does not act as a brake on innovation, but rather as a catalyst for a fairer, more transparent, and sustainable technological model. Artificial intelligence, as a driver of transformation, must serve a future that is not only digital, but also ecologically viable.

## 6 The legal loopholes in the current regulatory framework

Despite significant advances in the regulation of artificial intelligence in the European Union, the current regulatory framework still presents important loopholes that hinder comprehensive and effective governance, especially with regard to its environmental impact. Huarte (2023) argues that the forging of the environmental regime of ICTs is being left in the hands of the private sector, which is why it must be essential, on the part of European authorities, to establish a regulation that is flexible enough to allow innovation and changes in technology, but at the same time robust enough to guarantee legal certainty among operators, which must also include firmness in sustainability policies.

Although the AI Act establishes general principles such as transparency, human oversight, and the protection of fundamental rights, it does not explicitly include environmental criteria such as energy consumption, computational efficiency, or the carbon footprint of algorithmic models. This omission leaves a regulatory gap that may compromise the objectives of the European Green Deal and the digital ecological transition. Another critical aspect is the absence of binding technical standards that would allow homogeneous measurement of the environmental impact of AI systems. Although metrics and assessment tools are being developed, their adoption is still voluntary and lacks legal force. This prevents the establishment of minimum thresholds for energy efficiency or mandatory sustainability requirements for AI developers and users.

In the Spanish context, *Ley 7/2021* mentions AI as a key technology for decarbonization, but it does not establish specific obligations regarding its sustainable design or implementation. Furthermore, the possibility of applying Directive 2009/125 remains a subject of debate, due to the intangible nature of many of these systems and their dependence on complex infrastructures such as data centers.

Judge Frank H. Easterbrook referred, in 1996, to the concept of the "Law of the Horse" to describe the instinct of jurists to pass regulations applicable to each new sector that emerges in society. Easterbrook uses the analogy that there is no "Law of the Horse" to specifically regulate horses, but rather general laws are applied. In this way, what he intends to demonstrate is that existing laws are sufficient to regulate technology and that, therefore, creating specific laws for each new technology—in this case, AI—may lead to unnecessary complications in the legislative field. Nevertheless, although this topic may give rise to a debate of a more philosophical nature, I believe that artificial intelligence is changing the paradigm of society as we knew it, becoming involved in practically all aspects of our lives. Therefore, since it is so intrinsically linked to our protection as a society, it must be properly regulated so that it does not exceed limits that, otherwise, could prove to be harmful.

Ultimately, AI regulation must evolve towards a more holistic model, one that not only guarantees safety and fundamental rights, but also explicitly incorporates the principles of environmental sustainability. Only in this way will it be possible to build a digital ecosystem that serves both people and the planet. To achieve this, a multisectoral collaboration between researchers,

legislators, companies, and citizens is essential. Only through a comprehensive approach that combines innovation, regulation, ethics, and social awareness will it be possible to build an artificial intelligence that is not only intelligent, but also fair, transparent, and respectful towards the ecological boundaries of the planet.

## 7 Conclusions

The development and deployment of artificial intelligence must be guided not only by innovation and efficiency, but also by a deep commitment to environmental sustainability and ethical responsibility. As this study has shown, the environmental impact of AI—particularly in terms of energy consumption, water usage, and carbon emissions—requires urgent attention. Green algorithms, whether designed to be energy-efficient or used to address ecological challenges, represent a promising path toward reconciling technological advancement with planetary boundaries.

However, current regulatory frameworks, while still being developed, still present significant gaps in addressing the environmental dimensions of AI. The absence of binding standards and specific sustainability requirements limits the effectiveness of existing legislation. To ensure that AI contributes positively to both society and the environment, a holistic and adaptive legal model is needed: one that integrates sustainability as a core principle. The present paper aims to spark coordinated efforts among legislators, researchers, industry, and civil society to build a digital ecosystem that is not only intelligent and innovative but also fair, transparent, and ecologically viable.

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