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The Hidden Cost: The Environmental Impact of Artificial Intelligence - Assessing the Effectiveness of the EU AI Act and the Need for Additional Regulatory Measures

To what extent does the EU AI Act contribute to the mitigation of AI's environmental impact, and what supplementary regulatory measures are necessary?

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ABSTRACT

*The rapid advancement of Artificial Intelligence (‘**AI**’) has brought significant benefits across various sectors, yet it also poses substantial environmental challenges**.** This thesis, undertaken as part of the combined LL.M. Law in a Digital Economy and MA in Transnational Law program at the Universidade Católica Portuguesa, explores the environmental impact of AI and conducts an analysis of the effectiveness of the EU AI Act in addressing these challenges.*

The thesis proposes two primary regulatory measures: imposing stricter regulations on compute, i.e. the infrastructure underlying AI technologies, to address sustainability of hardware, resources and infrastructure in general; and implementing environmental harm-specific provisions through additions to the EU AI Act. This two-pronged approach aims to target regulation at component-level and system-level. Stricter component-level regulation would ultimately feed in to greater sustainability of AI and general computing, and therefore, provide positive benefits to other resource-intensive computing, such as blockchain.

By examining the relevant competition, innovation and environmental protection interests, this thesis aims to provide a balanced regulatory approach for mitigating AI’s environmental footprint.

List of Abbreviations

Artificial Intelligence	AI
Command-and-Control Regulation	CACs
Corporate Reporting Sustainability Directive (EU) 2022/2464	CSRD
Deep Learning	DL
Deep Neural Networks	DNNs
EcoDesign for Sustainable Products Regulation (EU) 2024/1781	ESPR
Environmental Impact Assessments	EIAs
European Artificial Intelligence Act (EU) 2024/1689	EU AI Act
European Code of Conduct for Data Centre Energy Efficiency	EU DC CoC
European Parliament	EP
Electronic Waste	E-waste
Fundamental Rights Impact Assessment	FRIA
Floating Point Operations Per Second	FLOPS
Generative Pre-trained Transformer	GPT
Graphics Processing Units	GPUs
Greenhouse Gas	GHG
High-Risk Artificial Intelligence Systems	HRAIS
Information and Communications Technology	ICT
Large Language Models	LLMs
Machine Learning	ML
Market-based Instruments	MBIs

Nationally Determined Contributions	NDPs
Natural Language Processing	NLP
Protection of the Environment through Criminal Law (EU) 2024/1203	PECL
Small and Medium Enterprises	SMEs
The European Commission's High-Level Expert Group	AI HLEG
The Organisation for Economic Co-operation and Development	OECD
The World Intellectual Property Organisation	WIPO
Treaty on the Functioning of the European Union	TFEU

Chapter 1

I. Introduction

Artificial Intelligence has rapidly integrated into our daily lives and various industries, driving significant advancements. Technologies such as voice assistants, (semi-) autonomous vehicles, and generative AI tools that create new content, are increasingly becoming commonplace.[1]

OpenAI's ChatGPT[2], a general-purpose AI system, has transformed content generation, attracting over 180.5 million users and generating 1.6 billion visits by February 2024,[3] just a year after surpassing 100 million monthly active users.[4] This success is bolstered by OpenAI's partnership with Microsoft, which provides significant financial backing and cloud resources, expanding ChatGPT's applications across multiple sectors.[5] Similarly, in biomedicine, AlphaFold has revolutionised protein structure prediction,[6] aiding drug discovery with highly accurate models using deep neural networks.[7] In finance, HSBC and Google Cloud's Anti-Money Laundering AI enhances efficiency by generating risk scores to detect financial crimes and streamline investigations, leveraging vast amounts of data to drive forward efficiency.[8] These are just some notable examples of AI's transformative power across sectors.

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[1] Martin Placek, 'Autonomous vehicles worldwide - statistics & facts' (*Statistia*, 18 December 2023) <Autonomous vehicles worldwide - statistics & facts | Statista> accessed 21 August 2024; Bret Kinsella, 'Voice Assistant Adoption Clusterin Around 50% of the Population' (voicebot.ai, 15 April 2022) <Voice Assistant Adoption Clustering Around 50% of the Population - Voicebot.ai> accessed 21 August 2024.

[2] *See OpenAI's, ChatGPT* <*ChatGPT*>.

[3] ibid.

[4] Wisernotify, 'ChatGPT User Growth: Reaching 200 Million Active Users' *(Wisernotify)* < ChatGPT User Growth: Reaching 200 Million Active Users (wisernotify.com)> accessed 23 June 2024.

[5] Microsoft, 'OpenAI forms exclusive computing partnership with Microsoft to build new Azure AI supercomputing technologies' (*Microsoft News Center*, 22 July 2019) <OpenAI forms exclusive computing partnership with Microsoft to build new Azure AI supercomputing technologies - Stories> accessed 15 May 2024.

[6] ibid.

[7] Zhenyu Yang, Xiaoxi Zeng, Yi Zhao and Rhunsheng Chen, 'AlphaFold2 and its applications of biology and medicine' (2023) 8 Signal Transcution and Targeted Therapy 115 <https://pubmed.ncbi.nlm.nih.gov/36918529/> accessed 15 May 2024.

[8] UK Finance, 'The Impact of AI in Financial Services: Opportunities, Risks and Policy Considerations' 23 (*UK Finance*, November 2023) <The impact of AI in financial services.pdf (ukfinance.org.uk)> accessed 15 August 2024.

AI has become a cornerstone of Industry 4.0, marking a significant shift towards digitisation across various industries. Advancements in high-performance computing, machine learning, and deep learning algorithms have fuelled this rapid integration.[9] The widespread availability of vast datasets[10] and scalable cloud-based solutions[11] have further accelerated AI adoption.

Looking to the future, numerous studies highlight AI's significant economic potential. Accenture predicts that AI could double annual global economic growth rates by 2035,[12] while PwC estimates that AI technologies could increase global GDP by up to 14% by 2030.[13] The World Intellectual Property Organisation ('**WIPO**') highlights that machine learning holds the most AI-related patents, with deep learning being the fastest-growing technology.[14] McKinsey projects that by 2030, around 70% of companies will have adopted at least one type of AI technology, contributing an additional $13 trillion to the global economy.[15]

However, alongside these advancements and rapid cross-sector adoption, the environmental impacts of AI have become increasingly apparent, gathering growing attention for policymakers, industry and the general public.

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[9] Zhou Shao, Ruoyan Zhai, Sha Yuan, Ming Ding, Yongli Wang, 'Tracing the evolution of AI in the past decade and forecasting the emerging trends' (2022) 209 Expert Systems with Applications, 118221 <Tracing the evolution of AI in the past decade and forecasting the emerging trends - ScienceDirect> accessed 2 June 2024.

[10] *See for example ImageNet or UCI Machine Learning Repository*.

[11] Paul Estrach, 'Scalability in Cloud Computing: A Deep Dive' (*Mega*, 18 August 2023) <Exploring Scalability in Cloud Computing: Benefits and Best Practices | MEGA> accessed 21 August 2024.

[12] Accenture, 'Artificial Intelligence Poised to Double Annual Economic Growth Rate in 12 Developed Economies and Boost Labor Productivity by up to 40 Percent by 2035, According to New Research by Accenture' (*Accenture*, 28 September 2016) <Artificial Intelligence Poised to Double Annual Economic Growth Rate in 12 Developed Economies and Boost Labor Productivity by up to 40 Percent by 2035, According to New Research by Accenture> accessed 23 July 2024.

[13] Jonathan Gillham, Lucy Rimmington, High Dance, Gerard Verweij, Anand Rao, Kate Barnard Roberts, Mark Paich, 'Macroeconomic Impact of Artificial Intelligence' (*PWC*, February 2018), 3 <macroeconomic-impact-of-ai-technical-report-feb-18.pdf (pwc.co.uk)> accessed 23 July 2024.

[14] WIPO, 'WIPO's First Technology Trends Study Probes Artificial Intelligence: IBM and Microsoft are Leaders Amid Recent Global Upsurge in AI Inventive Activity' (*WIPO*, 31 January 2019) <WIPO's First "Technology Trends" Study Probes Artificial Intelligence: IBM and Microsoft are Leaders Amid Recent Global Upsurge in AI Inventive Activity> accessed 23 July 2024.

[15] Jaques Bughin, Jeongmin Seong, James Manyika, Michael Chui, Raoul Joshi, 'Notes from the AI Frontier Modeling the Impact of AI on the World Economy' McKinsey Global Institute, September 2018, 30 <MGI-Notes-from-the-AI-frontier-Modeling-the-impact-of-AI-on-the-world-economy-September-2018.ashx (mckinsey.com)> accessed 23 July 2024.

The environmental footprint of AI differs significantly across systems, largely due to the varying computational requirements. Large Language Models ('**LLMs**'), such as those used in generative AI, exhibit a particularly high environmental toll. For instance, training OpenAI's GPT-3 consumed 1,287 MWh and emitted over 550 tonnes of CO2, the equivalent to 550 flights between New York and San Francisco.[16] Training these models requires extensive computational power, relying on energy-intensive Graphics Processing Units ('**GPUs**') for processing vast amounts of data.[17]

The infrastructure supporting AI, including data centres, also significantly contributes to environmental degradation. Data centres, necessary for cloud computing and storage, are scrutinised for their energy and water-intensive operations.[18] According to the International Energy Agency, data centres and transmission networks account for 1% to 1.5% of global electricity use and 0-6% of global carbon emissions.[19] Figures would need to be halved by 2050 to meet climate targets.[20]

It is not just the development of AI that is increasingly concerning, the application of AI in industries and projects can also promote unsustainable practices. For example, AI-driven initiatives like the collaboration between Microsoft and ExxonMobil to analyse drilling data illustrate how AI can enhance environmentally controversial industries.[21] While AI can improve efficiency and potentially reduce some environmental impacts, it also risks further entrenching practices that are harmful to the environment.

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[16] David Patterson, Joseph Gonzalez, Quoc Le, Chen Liang, Lluis-Miquel Munguia, Daniel Rothchild, David So, Maud Texier, Jeff Dean, 'Carbon Emissions and Large Neural Network Training' (*Cornell University*, 23 April 2021) <https://arxiv.org/ftp/arxiv/papers/2104/2104.10350.pdf> accessed 5 March 2024.

[17] ibid.

[18] Kaladhar Voruganti, Doron Hendel, 'What Generative AI means for Data Centres' (*Equinix*, 7 August 2023) <https://blog.equinix.com/blog/2023/08/07/what-generative-ai-means-for-data-centers/> accessed 10 March 2024; Shannon Osaka, 'A New Front in the Water Wars: You Internet Use' (*The Washington Post*, 25 April 2023) <https://www.washingtonpost.com/climate-environment/2023/04/25/data-centers-drought-water-use/> accessed 15 March 2024.

[19] ibid.

[20] ibid.

[21] ExxonMobil, 'Applying Digital Technologies to Drive Energy Innovation' (*ExxonMobil*) <Digital technologies | ExxonMobil> accessed 23 July 2024.

Predictions suggest that without substantial re-evaluation of AI development practices, the energy consumption relating to machine learning ('**ML**') training and associated data processing and storage could surpass that of the entire human workforce by 2025, constituting 3.5% of global electricity consumption.[22] This surge in energy use could significantly increase global electricity demand and potentially undermine the carbon-neutral benefits that AI may otherwise offer. Compared with pre-AI era figures where data centres accounted for only 1% of global electricity use, it constitutes a stark increase and underscores the urgent need for effective regulatory measures.[23]

At the same time, AI also offers positive benefits and may equally contribute to increased environmental sustainability. These include improving thermal energy system management, urban air quality, waste management, and improving cooling processes.[24] This complicates matters, creating somewhat of a regulatory conundrum.

Currently, the EU AI Act constitutes the most significant piece of legislation regulating AI at a transnational level. As will be examined further below, it fails to adequately address the scope of environmental impact caused by AI. Addressing AI's environmental impact presents several regulatory dilemmas. One challenge lies in conceptualising and quantifying environmental impacts accurately, given the varying nature of AI technologies. Additionally, there are interests, such as innovation, public safety, and competition, that must be balanced with environmental protection. Striking this balance is essential to ensure sustainable AI development without hampering technological progress - as is picking the right regulatory tools for the job.

Regulation is needed at both the component and system-level. At component-level, a combination of stricter prescriptive regulations and market-based instruments can drive higher sustainability standards in hardware, resources, and infrastructure. These improvements will, in turn, enhance sustainability at system-level. At system-level, the EU AI Act offers a suitable framework for

[22] Gartner, 'Gartner unveils Top Predictions for IT Organisations and Users in 2023 and Beyond' (Orlando, Florida, 18 October 2022) <https://www.gartner.com/en/newsroom/press-releases/2022-10-18-gartner-unveils-top-predictions-for-it-organizations-and-users-in-2023-and-beyond> accessed 15 March 2024.
[23] ibid.
[24] ibid (n14) 197.

enforcing stricter environmental standards through targeted additions and amendments. The Act's risk-based approach, which balances innovation, competition, and public safety; along with its flexibility and adaptability to emerging concerns; and sector-agnostic application, makes it well-suited for this role.

II. Research Questions

Despite widespread discussions about AI's adoption and its numerous benefits, there is a notable gap in addressing regulatory approaches to mitigate its environmental impact. Environmental sustainability of AI has appeared secondary in numerous discussions and policies, for example, as seen in the HAL Index Report which concluded that amongst 42 US-based organisations which produced policy papers relating to AI, the environment did not take priority.[25] The Ad Hoc Committee on AI further found that ethical considerations on the environmental sustainability of AI was underrepresented.[26]

This thesis seeks to fill that gap by exploring the multi-faceted environmental impacts of AI and evaluating the effectiveness of the current EU AI Act in addressing these issues, as well as suggesting proposals for amendment.

The following research questions will be addressed:

Q1. What are the known environmental impacts of AI, and how do they vary from other technologies?

Q2. How effective is the EU AI Act in addressing these environmental impacts?

[25] Daniel Zhang, Saurabh Mishra, Erik Brynjolfsson, John Etchemendy, Deep Ganguli, Barbara Grosz, Terah Lyons, James Manyika, Juan Carlos Niebles, Michael Sellitto, Yoav Shoham, Jack Clark, and Raymond Perrault, 'The AI Index 2021 Annual Report', AI Index Steering Committee, Human-Centered AI Institute, Stanford University, Stanford, CA.
[26] Isaac Ben-Israel, Jorge Cerdio, Arisa Ema, Leche Friedman, Marcelo Ienca, Alessandro Mantelero, Eviatar Matania, Catelijne Muller, Hideaki Shiroyama, and Effy Vayena (2020), 'Towards regulation of AI systems', Council of Europe Study DGI 16 <https://rm.coe.int/prems-107320-gbr-2018-compli-cahai-couv-texte a4-bat-web/1680a0c17a.> accessed 28 July 2024.

Q3. What should the objectives and scope of regulations of AI's or, more generally, technology's environmental impacts be, and how should they differ from the EU AI Act?

Q4. How can the regulation of negative environmental impacts of AI ensure a balance between individual freedoms, innovation and competition that, amongst others, may offer positive (environmental) benefits?

III. Methodology

The jurisdictional focus of this thesis is on transnational law, with a particular emphasis on the EU AI Act, as the global cross-border nature of technology and environmental harm necessitates a multi-national, harmonised and collaborative approach.[27] The following scrutinises the Act's provisions from an environmental protection standpoint, evaluates its effectiveness, and identifies gaps requiring improvements.

The research is primarily doctrinal and comparative legal research, albeit it analyses existing public data on the environmental impacts of AI and compute. It does not seek to create new data. The methodology is structured in two phases.

1. Data and Literature Review: A literature review to highlight the high rate of AI adoption across sectors and identify the known environmental impacts of AI.

2. Analysis: The analysis categorises the environmental harms of AI into direct and indirect impacts, including greenhouse gas ('**GHG**') emissions, water consumption, and extending to social impacts. It employs a comparative approach to evaluate the EU AI Act in light of these impacts and make recommendations which incorporate national regulatory efforts to mitigate these harms.

[27] Lewin Schmitt, 'Mapping global AI governance: a nascent regime in a fragmented landscape' (2022) AI Ethics 2, 303 <Mapping global AI governance: a nascent regime in a fragmented landscape | AI and Ethics (springer.com)> accessed 10 June 2024.

III.I Limitations

1. There is a notable scarcity of data regarding the environmental footprint of AI systems due to the lack of disclosure by companies using these technologies. Consequently, this thesis relies on the available disclosed data, most of which is compute-specific rather than AI-specific, and third-party analyses. It is therefore acknowledged that these sources may not fully capture the extent of the *de facto* environmental impact of AI and its related compute.

2. The proposals in this thesis are based on the available information and offer a suggested regulatory approach rather than a detailed regulatory framework, which is beyond the scope of this thesis.

3. For the sake of limiting the scope of this thesis, the substantial analysis centres on the EU AI Act as the most substantial piece of transnational legislation on AI regulation. However, it is acknowledged that other transnational frameworks addressing AI and its environmental impacts may exist or be a more suitable approach for addressing AI's environmental impacts.

III.II Structure

Chapter 1 examines data on AI's environmental impact throughout its lifecycle, from production to disposal, categorising impacts as direct and indirect.
Chapter 2 assesses the EU AI Act's current form, identifying gaps in addressing AI's negative environmental impacts.
Chapter 3 synthesises findings from Chapters 1 and 2 to propose solutions for addressing the identified regulatory gaps efficiently.

IV. Definitions

The following will aim to synthesise the ongoing and increasing discourse on the environmental impact of AI and assess the EU AI Act in light of this impact. In order to do so, it is firstly important to understand what AI is legally defined as.[28]

IV.I (Legal) Definitions

The term 'artificial intelligence' (‘**AI**’) lacks a universally agreed-upon definition due to its broad and evolving nature.[29] Coined by Professor John McCarthy in 1956, AI was initially defined as ‘the science and engineering of making intelligent machines.’[30] Since then, AI has progressed to systems more and more capable of autonomous decisionmaking.

Broadly, AI refers to algorithms designed to solve problems or perform tasks.[31] Narrowly, it mimics human cognitive thinking and decision-making.[32] The European Commission’s High-Level Expert Group on AI (‘**AI HLEG**’) characterises AI as systems that display intelligent behaviour by analysing the environment and taking autonomous actions to achieve goals.’[33] The European Artificial Intelligence Act (‘**EU AI Act**’) defines AI as ‘a machine-based system designed to operate with varying levels of autonomy and that may exhibit adaptiveness after deployment and that, for explicit or implicit objectives, infers, from input it receives, how to generate outputs such as predictions, content, recommendations, or decisions that can influence physical or virtual environments.’[34] According to the International Standardisation Organisation, AI is defined as ‘a technical and scientific field devoted to the engineered system that generates

[28] *An examination of technical definitions can be found in the Annex.*
[29] Stuart Russell, Peter Norvig, *Artificial Intelligence: A modern approach* (4th ed., Pearson 2020).
[30]John McCarthy, ‘What is Artificial Intelligence’ (*Stanford University*, 12 December 2007) <https://www-formal.stanford.edu/jmc/whatisai.pdf> accessed 22 May 2024.
[31] ibid.
[32] ibid (n27).
[33] High-Level Expert Group on Artificial Intelligence, A definition of AI: Main capabilities and scientific disciplines (The European Commission 2018). <https://digital-strategy.ec.europa.eu/en/library/definition-artificial-intelligence-main-capabilities-and-scientific-discipline> accessed 24 March 2024.
[34] The European Artificial Intelligence Act (EU) 2024/1689 <https://artificialintelligenceact.eu/article/3> accessed 17 April 2024.

outputs such as content, forecasts, recommendations or decisions for a given set of defined objectives.' [35]

These definitions of AI converge on several key elements: AI is characterised as systems or algorithms that solve problems and make decisions, often emulating human cognitive abilities. They demonstrate intelligence behaviour by analysing their environment and taking (semi-) autonomous action to achieve certain objectives.[36] Overall, these definitions collectively portray AI as autonomous, goal-oriented systems capable of generating diverse outputs to achieve defined objectives.

Rather than contributing to a further proliferation of definitions within academic literature, this thesis adopts the EU AI Act's definition, which emphasises adaptiveness without limiting autonomy. A broader definition, while inclusive, makes targeted regulation challenging, as it encompasses diverse AI systems with varying risks and capabilities.

IV.II How does AI fit within broader computing?

AI constitutes one segment of broader computing, which itself carries environmental implications. However, why prioritise AI? The focus on AI is driven by both qualitative and quantitative differences to other technologies.

AI's widespread adoption across industries and unique potential to reshape economies raise distinct environmental concerns. For instance, compute usage relating to AI training grew 300,000-fold between 2012 and 2019, excluding the latest models such as OpenAI's GPT-models.[37] LLMs

[35] International Standard Organisation, SO/IEC 22989:2022 (2022) <https://www.iso.org/standard/74296.htm> accessed 10 April 2024.

[36] European Union (2018). Coordinated Plan on Artificial Intelligence <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52018DC0795> accessed 3 September 2024.

[37] Karen Hao, 'The computing power needed to train AI is now rising seven times faster than ever before' (*MIT Technology Review*, 11 November 2019) <The computing power needed to train AI is now rising seven times faster than ever before | MIT Technology Review> accessed 24 August 2024.

are particularly acknowledged for their significant environmental footprint and addressing these systems offers a strategic opportunity for substantial environmental improvement.[38]

Addressing AI's environmental impact is not just about current challenges but also about shaping the future trajectory of technological development. As AI integrates further across sectors, its energy demands, water consumption and waste generation could escalate, underscoring the need for proactive regulation to ensure sustainable and long-term growth.

Nevertheless, it has to be acknowledged that some of the findings of this thesis may extend to compute-intensive applications, such as proof-of-work blockchain systems, which similarly require significant energy and resources.[39] These systems, like AI, can have profound environmental impacts, making them equally important targets for regulatory scrutiny. However, the unique qualitative characteristics of AI and its impressive quantitative growth are deserving of particular attention. Additionally, by understanding the effects of AI, we also gain insights into the broader category of computationally intensive technologies, providing a foundation for more comprehensive and effective environmental policies across the digital landscape.

[38] Greg Smith, Michael Bateman, Remy Gillet, Eystein Thanisch, 'Environmental Impacts of Large Language Models' (*Cutter*, 24 August 2023) <Environmental Impact of Large Language Models | Cutter Consortium> accessed 10 July 2024.

[39] European Environment Agency, 'Blockchain and the Environment' Briefing no. 15/2020 <Blockchain and the environment — European Environment Agency (europa.eu)> accessed 15 August 2024.

Chapter 2

I. The Environmental Impact of AI

AI's environmental footprint spans its entire lifecycle, from production to disposal, involving significant energy consumption, resource use, and waste generation. Recognising the need to reconcile technological progress with sustainability, the EU has promoted a digital and ecological 'twin' transition[40] under the Green Deal.[41]

This chapter examines the environmental footprint of AI at each lifecycle stage, distinguishing between direct and indirect environmental impacts as categorised by the Organisation for Economic Co-operation and Development ('**OECD**').[42]

I.I Conceptualising Environmental Impact

AI's environmental impact can be categorised into direct and indirect effects:

- Direct environmental impacts of AI encompassing the entire lifecycle of AI compute resources, including production, operation, and disposal.[43]

- Indirect environmental impacts involving broader effects from AI use, including both positive and negative outcomes from increased consumption and rebound effects spurring, *i.a*, increased consumptive behaviour.[44]

[40] The European Commission, 'Strategic Foresight Report Twinning the green and digital transitions in the new geopolitical context' (The European Commission Newsroom), <https://joint-research-cen- tre.ec.europa.eu/jrc-news-and-updates/twin-green-digital-transition-how-sustainable-digi- tal-technologies-could-enable-carbon-neutral-eu-2022-06-29_en> accessed 20 June 2024.

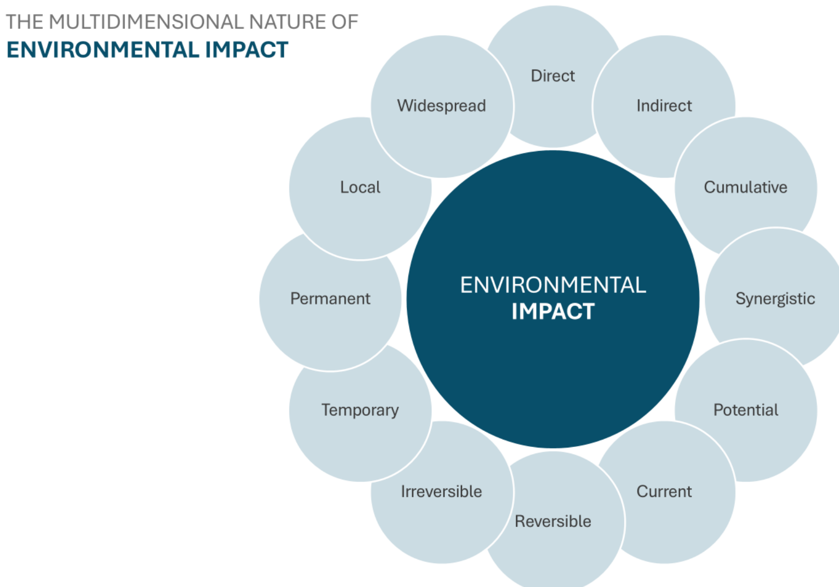
[41] The European Green Deal (COM/2019/640 final) <The European Green Deal - European Commission (europa.eu)> accessed 30 July 2024.

[42] Frans Berkhout, Julia Hertin 'Impacts of information and communication technologies on environmental sustainability: speculations and evidence' (2001), Report to the OECD.

[43] ibid.

[44] ibid.

However, environmental impacts are multidimensional and can be classified in various ways: reversible, irreversible, temporary, permanent, cumulative, synergistic, current, potential, local, widespread, and more.[45]



The complexity of conceptualising environmental impact is compounded when considering AI's specific effects, limited by several factors which make regulation even more challenging:

1. There is a lack of specific data on AI's environmental impact.

2. Available data primarily pertains to the environmental impact of underlying technologies constituting AI, such as broader information and communications technologies ('**ICT**') of AI compute resources, rather than being AI-specific. AI relies on physical infrastructure, which individually and collectively demands significant amounts of natural resources and materials.[46]

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[45] Saheed Matemilola, Habeeb Adedotoun Alabi, 'Environmental Impact' in Samuel Idowu, René Schmidpeter, Nicholas Capaldi, Liangrong Zu, Mara Del Baldo, Rute Abreu, Encyclopedia of Sustainable Management (Springer 2021).

[46] OECD, 'Measuring the Environmental Impacts of Artificial Intelligence Compute and Applications, the AI Footprint' (OECD Digital Economy Papers, November 2022) <https://www.oecd-ilibrary.org/docserver/7babf571-en.pdf?expires=1719322492&id=id&accname=guest&checksum=4390296A9B8960CABEB470F022A8301C> accessed 20 June 2024.

3. There are multiple dimensions to environmental impact as outlined above. For example, long-term environmental consequences of AI may only become clear over time, making it difficult to assess impacts in the present.

Focusing solely on the nature of environmental impacts is not enough for effective regulation. Instead, regulations should target measurable impacts like GHG emissions, water usage, and electricity consumption, which provide clearer, quantifiable goals. Chapter 4 will explore this further.

However, considering the multidimensional nature of environmental impacts is still valuable. It helps ensure regulations are comprehensive and address all relevant aspects. The next section will examine these impacts in more detail.

I.II Direct Environmental Impacts of AI

The direct environmental impacts of AI primarily stem from the lifecycle of AI compute resources. While these impacts are largely negative, AI applications also offer potential positive effects.[47]

I.II.I Production

The production stage of AI involves the development of computing hardware, such as GPUs and semiconductors. As noted by Crawford, the environmental impacts at this stage include deforestation, erosion, toxic waste disposal, water use (particularly during semiconductor fabrication) and groundwater pollution.[48] These issues arise from the mining, smelting and refining processes that are integral to hardware production.[49]

[47] Eva Barteková, Peter Börkey, 'Digitalisation for the transition to a resource efficient and circular economy', (2022) OECD Environment Working Papers 192 <Digitalisation for the transition to a resource efficient and circular economy | OECD> accessed 20 June 2024.
[48] Kate Crawford, *Anatomy of an AI System* (Share Foundation, 2018).
[49] ibid (n43).

I.II.II Operation

I.II.II.I Data Collection and Processing

The environmental impacts of AI operations, particularly during data collection, processing, and deployment, are more easily quantifiable, with a focus on GHG emissions[50], energy use, and water consumption.

Data collection relies on various devices and sensors that aggregate information from sources like internet crawls and real-time sensors.[51] Storing and transmitting this data requires large, energy-intensive data centres built from materials like silicon and copper.[52] These centres demand constant power and cooling, generating substantial heat.

Efforts are underway to reduce these impacts, such as using renewable energy to power data centres[53] and recycling the heat they produce.[54] However, cooling still consumes vast amounts of water. Estimates suggest AI-related data centres use enough water annually to fill 2,500 Olympic-sized pools,[55] with each 20-50 AI queries from systems such as ChatGPT consuming about 500ml of water.[56] Water use may also be indirectly driven by electricity generation for AI operations. Research suggests AI could account for 4.2-6.6 billion cubic metres of water withdrawal by 2027,

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[50] Udit Gupta, Young Geun Kim, Sylvia Lee, Jordan Tse, Hsien-Hsin S. Lee, Gu-Yeon Wei, David Brooks, Carole-Jean Wu, 'Chasing Carbon: The Elusive Environmental Footprint of Computing' (*Cornell University*, 2020) <[2011.02839] Chasing Carbon: The Elusive Environmental Footprint of Computing (arxiv.org)> accessed 24 June 2024.

[51] Leila Acaroglu, 'The Hidden Environmental Impacts of AI' (*LinkedIn*, 19 February 2024) <https://www.linkedin.com/pulse/hidden-environmental-impacts-ai-leyla-acaroglu-xryyc/> accessed 20 May 2024.

[52] Copenhagen Centre on Energy Efficiency, 'Environmental sustainability of data centres: A need for a multi-impact and life cycle approach' (*Copenhagen Centre on Energy Efficiency*, 7 February 2020) <Environmental sustainability of data centres: A need for a multi-impact and life cycle approach - Copenhagen Centre on Energy Efficiency (unepccc.org)> accessed 24 August 2024.

[53] Catherine Sgeglia Nin, 'Google signs renewable energy deal to power AI data centers' (*RCRWirelessNews*, 21 August 2024) <Google signs renewable energy deal to power AI data centers (rcrwireless.com)> accessed 24 August 2024.

[54] Noah Nkonge, 'What is Data Center Heat Export and How Does it Work?' (*Equinox*, 5 June 2024) <What Is Data Center Heat Export and How Does it Work? - Interconnections - The Equinix Blog> accessed 24 August 2024.

[55] Microsoft, '2024 Environmental Sustainability Report' <2024 Environmental Sustainability Report | Microsoft CSR> accessed 29 July 2024.

[56] Frederico Guerrino, 'AI's Unsustainable Water Use: How Tech Giants Contribute to Global Water Shortages' (*Forbes*, 14 April 2023) '<AI'S Unsustainable Water Use: How Tech Giants Contribute To Global Water Shortages (forbes.com)> accessed 1 August 2024.

exceeding the total annual water use of 4-6 'Denmarks' or half of the UK.[57] That being said, it is estimated that *only* about 33-50% of data centre operators report their water use[58] - there is still comparatively little known as to the *de facto* water use as opposed to energy consumption or GHG emissions. Additionally, geographic differences in sustainability are significant. For example, U.S data centres draw water from 90% of national watersheds.[59]

Electricity demand is also a concern, with the International Energy Agency estimating that data centres could consume as much electricity as Japan (over 1000TWh) by 2026.[60] The growing need for computational power to process increasing data volumes will only intensify this demand.[61]

I.II.II.II Model Training

Training AI models is one of the most energy-intensive stages of the AI lifecycle. This stage consumes more energy than traditional data centre activities - LLMs like GPT-3 can consume as much energy as 130 U.S. homes annually.[62] This process, although dependant on, *i.a.*, the system's specific architecture, as well as the volume and quality of data, requires thousands of GPUs and high-performance chips, each specialised AI rack[63] using as much power as 25 houses.[64] Strubell

[57] Pengfei Li, Jianyi Yang, Mohammad A. Islam, Shaolei Ren, 'Making AI Less "Thirsty": Uncovering and Addressing the Secret Water Footprint of AI Models' (*Cornell University*, 29 October 2023) <https://arxiv.org/abs/2304.0327> accessed 9 May 2024.

[58] Jacqueline Davis, Daniel Bizo, Andy Lawrence, Owen Rogers, Max Smolaks 'Uptime Institute Global Data Center Survey Results 2022' The Uptime Institute (14 September 2022) <https://uptimeinstitute.com/uptime_assets/4d10650a2a92c06a10e2c70e320498710fed2ef3b4 02aa82fe7946fae3887055-2021-data-center-industry-survey.pdf> accessed 10 July 2024; Google Cloud, 'Carbon Footprint reporting methodology' (Google Cloud) <https://cloud.google.com/carbon-footprint/docs/methodology> (accessed 10 July 2024); David Mytton, 'Data centre water consumption', 2021 npj 4/1 Clean Water 11.

[59] Andrew Chapman, 'U.S. Data Centers Rely on Water from Stressed Basins' (*EC*, 12 July 2021) <U.S. Data Centers Rely on Water from Stressed Basins - Eos> accessed 1 August 2024.

[60] IEA, 'Digitalization & Energy' (November 2017) <https://iea.blob.core.windows.net/assets/b1e6600c-4e40- 4d9c-809d-1d1724c763d5/DigitalizationandEnergy3.pdf> accessed 30 July 2024.

[61] Pablo Villalobos, Anson Ho, Jaime Sevilla, Tamay Basiroglu, Lennart Heim, Marius Hobbhahn, 'Will We Run Out of Data? Limits of LLM Scaling Based on Human-Generated Data' (6 June 2024) <https://epochai.org/blog/will-we-run-out-of-data-limits-of-llm-scaling-based-on-human-generated-data> accessed 2 June 2024.

[62] James Vincent, 'How much electricity does AI consume' (*The Verge*, 16 February 2024) <How much electricity do AI generators consume? - The Verge> accessed 24 August 2024.

[63] ibid.

[64] Danny Quinn, 'Why AI's growth makes datacentre sustainability more important than ever' (*Computerweekly.com*, 8 September 2023) <https://www.computerweekly.com/blog/Green-Tech/Why-AIs-growth-makes-datacentre-sustainability-more-important-than-ever> accessed 10 May 2024.

et al. found that the GHG emissions from training an NLP system are equivalent to 300 flights between New York and San Francisco.[65]

The carbon footprint of training AI models is substantial,[66] but a lack of standardised reporting by tech companies makes it difficult to measure precisely.[67] Research shows that training AI is more carbon-intensive than using the trained models for inference.[68] Although renewable energy or carbon offsets could reduce emissions, the challenge remains that much of this energy is still sourced from non-carbon-neutral sources.[69] Additionally, renewable energy availability depends on infrastructure to store and distribute it.[70]

Similar to other AI lifecycle stages, water usage is another concern. Cooling the processors used during AI training requires large quantities of (fresh) water. For instance, a data centre serving OpenAI in West Des Moines, Iowa, consumed about 6% of the district's water in July 2022, just before the training of GPT-3 was completed.[71]

I.II.II.III Inference

After training, AI models enter the inference phase, where they process live data to make predictions or complete tasks. The energy usage during inference varies based on the system's architecture and parameters. A study by Cornell University, which analysed the environmental

[65] Emma Strubell, Ananya Ganesh, and Andrew McCallum. 2019. Energy and Policy Considerations for Deep Learning in NLP. In Proceedings of the 57th Annual Meeting of the Association for Computational Linguistics, pages 3645–3650, Florence, Italy. Association for Computational Linguistics.
[66] Aimee van Wynsberghe, 'Sustainable AI: AI for sustainability and the sustainability of AI' (2021) AI and Ethics 1, 213, 215.
[67] Akshat Rathi, Natasha While, 'How tech companies are obscuring AI's real carbon footprint' (*BNN Bloomberg*, 21 August 2024) <How tech companies are obscuring AI's real carbon footprint – BNN Bloomberg> accessed 24 August 2024.
[68] Renée Cho, 'AI's Growing Carbon Footprint' (*State of the Planet*, 9 June 2023) <AI's Growing Carbon Footprint – State of the Planet (columbia.edu)> accessed 24 August 2024.
[69] ibid (n62).
[70] ibid.
[71] Kate Crawford, 'Generative AI's environmental costs are soaring - and mostly secret' (*Nature*, 20 February 2024) <Generative AI's environmental costs are soaring — and mostly secret (nature.com)> accessed 10 June 2024.

footprint of 88 ML systems, found that training requires more carbon than inference.[72] For larger AI models, it would take approximately 204.5 million inference interactions to match the carbon impact of training.[73]

However, most AI computation occurs during inference, with Amazon Web Services estimating that 90% of its workload happens at this stage.[74] As AI becomes more integrated into daily applications, the energy demands of inference are likely to increase.

I.II.II.IV Implementation

The carbon footprint of AI implementation is significant, especially for systems that depend on energy-intensive GPUs in data centres. Beyond operational efficiency, AI's environmental impact heavily depends on the energy sources powering these systems. Regional differences in electricity generation, from fossil fuels to renewable energy, mean that the carbon intensity of the electricity used play a crucial role in shaping AI's overall environmental footprint.[75]

I.II.II Disposal

The lifecycle of AI compute ends with the disposal of hardware, contributing to the global electronic waste ('**e-waste**') problem. Due to rapid technological advancements, AI hardware often has a short lifespan. Disposing of outdated or malfunctioning equipment generates e-waste, which contains toxic substances like lead, mercury and cadmium and which, according to the Sustainable

[72] Alexandra Sasha Luccioni, Yacine Jernite, Emma Strubell, 'Power Hungry Processing: Watts Driving the Cost of AI Deployment?' (Cornell University, 28 November 2023) <https://arxiv.org/abs/2311.16863> accessed 11 May 2024.

[73] John Naghton, 'Why AI is a Disaster for the Climate' (The Guardian, 23 December 2023) <https://www.theguardian.com/commentisfree/2023/dec/23/ai-chat-gpt-environmental-impact-energy-carbon-intensive-technology> accessed 11 May 2023.

[74] David Patterson, Joseph Gonzalez, Quoc Le, Chen Liang, Lluis-iquel Mungeria, Daniel Rothchild, David So, Maud Texier, Jeff Dean, 'Carbon Emissions and Large Neural Network Training' (Cornell University, 21 April 2021) <[2104.10350] Carbon Emissions and Large Neural Network Training (arxiv.org)> accessed 10 June 2024.

[75] Shaolei Ren, Adam Wierman, 'The Uneven Distribution of AI's Environmental Impacts' (Harvard Business Review, 15 July 2024) <The Uneven Distribution of AI's Environmental Impacts (hbr.org)> accessed 28 August 2024.

Infrastructure Alliance, constitutes about 25% of global e-waste.[76] This poses health risks and exacerbates socio-political issues, as e-waste is frequently exported to developing countries.[77]

While initiatives like the EU's Sustainable Products Initiative[78] aim to promote circular lifecycles of ICT systems, a significant gap remains between the amount of e-waste generated and what is recycled. There is also a notable gap in AI-specific e-waste data.[79]

I.III Indirect Environmental Impacts of AI Compute

The indirect environmental impacts of AI are challenging to quantify, as they stem from broader societal changes influenced by AI applications. For example, AI-powered recommender systems in e-commerce can lead to increased consumer behaviour, which in turn drives resource consumption and waste.[80] This phenomenon is an example of the Jevons Paradox, where efficiency gains can inadvertently exacerbate environmental issues.[81]

The transformative implementation of AI technologies also introduces environmental challenges, particularly through AI-driven automation, which can amplify consumption and waste, further contributing to environmental degradation. Additionally, ethical concerns arise when AI is used to manage environmental systems, as flawed or biased data can result in inaccurate decision-making that harms ecological conservation efforts.

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[76] Sustainable Digital Infrastructure Alliance, The Roadmap to Sustainable Digital Infrastructure by 2030 (*SDIA*, 2022) <https://sdialliance.org/roadmap> accessed 16 June 2024.

[77] Michelle Heacock, Carol Bain Kelly, Kwadwo Ansong Asante, Linda S. Birnbaum, Åke Lennart Bergman, Marie-Noel Bruné, Irena Buka, David O. Carpenter, Aimin Chen, Xia Huo, Mostafa Kamel, Philip J. Landrigan, Federico Magalini, Fernando Diaz-Barriga, Maria Neira, Magdy Omar, Antonio Pascale, Mathuros Ruchirawat, Leith Sly, Peter D. Sly, Martin Van den Berg, and William A. Suk, 'E-waste and harm to vulnerable populations: a growing global problem', (2016) 124 Environmental Health Perspectives 5, 550-555.

[78] Euractive, 'Sustainable Products Initiative' (February 2022) <https://en.euractiv.eu/wp-content/uploads/sites/2/special-report/Sustainable-products-initiative-Special-Report.pdf> accessed 10 July 2024.

[79] OECD, Measuring the Digital Transformation, Organisation for Economic Co-Operation and Development (*OECD*, 2019), <https://doi.org/10.1787/888933931086> accessed 15 June 2024.

[80] Erik Hermann, Artificial intelligence in marketing: friend or foe of sustainable consumption (2021) 38 AI & Soc 1975.

[81] Carsten Paul, Anja-Kristina Techen, James Scott Robinson, Rebound effects in agricultural land and soil management: Review and analytical framework, (2019) 227 Journal of Cleaner Production 1054.

AI's environmental impacts vary across regions, revealing disparities in environmental equity. Communities in different geographical regions experience AI's environmental impact in varied ways. For instance, the Lefdal Mine Data Center in Norway uses 100% renewable hydropower and seawater cooling,[82] while Google's data centres in Finland run on 97% carbon-free energy.[83] In contrast, Google's data centres in Asia only use 4-18% carbon-free energy, relying heavily on fossil fuels.[84] Water consumption also presents regional challenges; data centres in water-scarce areas like Arizona[85] and Chile[86] can exacerbate existing water shortages for local communities.

I.III.I Positive Indirect Environmental Impact of AI Compute

In spite of the above, AI also offers potential solutions to some of the world's most pressing environmental challenges. The European Commission acknowledges this in its 2018 communication on AI: 'AI can be used positively - from treating chronic diseases or reducing fatality rates in traffic accidents to fighting climate change or anticipating cybersecurity threats.'[87] Similarly, the 2020 European Commission White Paper notes its 'significant role in achieving the Sustainable Development Goals'.[88]

When assessing AI's negative environmental impacts, it is crucial to also acknowledge its positive contributions. Any regulatory efforts must avoid stifling innovation that could lead to meaningful advancements in addressing climate challenges.

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[82] Business Norway, 'Leftdal Mine Datacentre is a large-scale data centre in a deep Norwegian mine' (Business Norway, 29 April 2024) <Leftdal Mine Datacenter is a large-scale data centre in a deep Norwegian mine (*businessnorway.com*)> accessed 11 June 2024.
[83] Steven Downes, 'How will Google's Finnish Data Centre Heat Reuse Plan Work' (*Sustainability Magazine*, 24 May 2024) <How Will Google's Finnish Data Centre Heat Reuse Plan Work? | Sustainability Magazine> accessed 25 August 2024.
[84] ibid.
[85] Cameron Polom, 'Data centres consume millions of gallons of Arizona water daily' (*abc*, 1 July 2021) <Data centers consume millions of gallons of Arizona water daily (abc15.com)> accessed 22 June 2024.
[86] Reuters, 'Chile Partially Pulls Google Data Center Permit, Seeks Tougher Environmental Checks' (*U.S News*, 27 February 2024) <Chile Partially Pulls Google Data Center Permit, Seeks Tougher Environmental Checks (usnews.com)> accessed 23 June 2024.
[87] The European Commission, 'Communication Artificial Intelligence for Europe' (25 April 2018) <Communication Artificial Intelligence for Europe | Shaping Europe's digital future (europa.eu)> 30 July 2024.
[88] The European Commission, 'White Paper on Artificial Intelligence - A European Approach to Excellence and Trust' (The European Commission, 19 February 2020) <commission-white-paper-artificial-intelligence-feb2020_en.pdf (europa.eu)> accessed 20 June 2024.

Broadly, AI may be used to transform unstructured data into useful information, for example, through leveraging satellite imagery to determine areas particularly vulnerable to flooding or experiencing deforestation.[89] Further, AI may provide more accurate predictions on climate adaptation and mitigation strategies, such as solar power generation or agricultural yield through using past data.[90] It may also be employed to optimise systems, such as heating and cooling. For example, DeepMind leverages machine learning to promote system efficiency, and its application within data centre cooling systems has reduced energy usage by approximately 30-40%.[91]

Quite ironically, AI is also being employed at a much more international scale, with the United Nations Framework Convention on Climate Change partnering with Microsoft to use AI and advanced data technology to track global carbon emissions and monitor progress under the Paris Agreement.[92] AI is further being applied by the European Space Agency's 'Destination Earth' project to forecast and improve resilience against climate change.

There are varying estimates as to which extent AI may help in achieving global sustainability targets. The Boston Consulting Group has estimated that AI could help reduce GHG emissions by 2.6 to 5.3 gigatons, constituting 5-10% of total global emissions.[93] PwC found that AI could reduce GHG emissions by 4%, 2.4 gigatons, by 2030.[94]

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[89] Global Partnership on AI Report, 'Climate Change and AI' (*GPAI*, November 2021) 18 <https://www.gpai.ai/projects/climate-change-and-ai.pdf> accessed 10 July 2024.

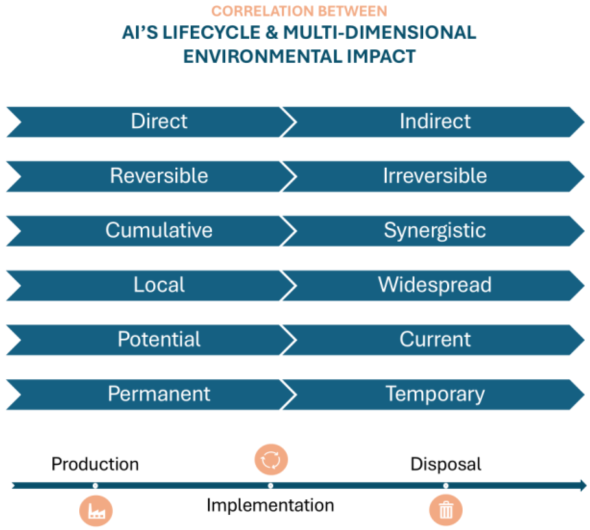
[90] ibid.

[91] ibid (n76) 90.

[92] UNFCCC, 'UNFCCC partners with Microsoft to use AI and advanced data technology to track global carbon emissions and assess progress under the Paris Agreement' (29 November 2023) <https://unfccc.int/sites/default/files/resource/UNFCCC_Microsoft_Partnership_2023.pdf> accessed 15 July 2024.

[93] Charlotte Degot, Sylvain Duranton, Michel Frédeau, Rich Hutchinson, 'Reduce Carbon and Costs with the Power of AI' (BCG, 16 January 2021) <Reduce Carbon and Costs with the Power of AI | BCG> accessed 28 July 2024.

[94] PWC, 'Using AI to better manage the environment could reduce greenhouse gas emissions, boost global GDP by up to US $5 trillion and create up to 38m jobs by 2030' (PWC, 16 April 2019) <Using AI to better manage the environment could reduce greenhouse gas emissions, boost global GDP by up to US $5 trillion and create up to 38m jobs by 2030 (*pwc.com*)> accessed 27 July 2024.



II. Environmental Impact as a Legal Problem?

AI's environmental impact is a classic example of a negative externality - an economic activity that imposes costs on third parties which are not accounted for in the market price.[95] Carbon emissions, energy consumption, and resource depletion are among the externalised costs borne by society as a whole. Addressing these challenges requires framing environmental impact as a legal problem, necessitating coordinated regulatory measures.

Regulatory frameworks can help internalise these externalities, encouraging developers and users to account for environmental costs.[96] It has been argued that the dynamic and complex nature of environmental challenges is suitable for regulatory measures[97] and the polycentric nature of the climate change problem extending across sectors requires an approach to the 'all of society' problem.[98]

[95] Thomas Helbling, 'Externalities: Prices do not capture all costs' (IMF) <Externalities: Prices Do Not Capture All Costs (imf.org> accessed 29 July 2024.
[96] Eloise Scotford, 'Legislation and the Stress of Environmental Problems' (2021) 74 Current Legal Problems 1, 299 <Legislation and the Stress of Environmental Problems | Current Legal Problems | Oxford Academic (oup.com)> accessed 28 July 2024.
[97] ibid.
[98] Eloise Scotford and Stephen Minas, 'Probing the Hidden Depths of Climate Law: Analysing National Climate Change Legislation' (2019) 28(1) Review of International and Comparative Environmental Law 67 <Probing the

However, regulation must strike a careful balance. Overregulation risks stifling innovation, while underregulation could allow unsustainable practices to continue. A well-coordinated regulatory approach will need to account for both the environmental costs and the potential of AI to drive forward positive change. This balance is important to ensure that AI continues to advance while contributing to a sustainable future.

III. Summary

In summary, the environmental impact of AI is a significant and complex issue that stretches across its entire lifecycle from production to operation, inference and disposal. This chapter highlights AI's and, more broadly, compute's far-reaching and multi-dimensional impacts, which have both direct and indirect effects that pose regulatory challenges.

Direct environmental impacts arise from the entire lifecycle of AI, including production, operation and disposal. Production often involves mining and manufacturing that contribute to deforestation, toxic waste, and water pollution. The operational stage of AI, particularly during data collection, processing and model training, consumes vast amounts of energy and water. Disposal of AI hardware contributes to the growing global e-waste problem, raising concerns about toxic waste and socio-political issues.

Indirect environmental impact includes rebound effects. AI's impact is also unevenly distributed geographically, with some regions benefiting from renewable energy sources while others rely heavily on fossil fuels, exacerbating environmental inequity.

That being said, AI may offer positive environmental contributions which must be considered in regulatory approaches. AI has the potential to optimise systems, provide accurate climate predictions, and support efforts in achieving sustainability goals.

Hidden Depths of Climate Law: Analysing National Climate Change Legislation by Eloise Scotford, Stephen Minas :: SSRN> accessed 27 July 2024.

It is clear that there is an environmental problem relating to this rapid growth and adoption of such environmentally taxing AI systems, however, the full extent of the problem is not yet clear due to data limitations. The problem also is predicted to only increase with the number of computational operations used to create the largest AI models doubling every ten months.[99]

Regulating AI's environmental impact is complicated due to limited data availability, especially on indirect impacts, and the difficulty in tracking long-term or delayed consequences. Much of the environmental impact is created at infrastructure and component level but also at system level. Going forward, regulation must consider the multiple impacts to the environment at both of these levels. The following chapters will consider how the EU AI Act considers these impacts, and what additional measures are needed.

[99] Will Henshall, 'The Billion-Dollar Price Tag of Building AI' (*Times,* 3 June 2024) <The Billion-Dollar Price Tag of Building AI | TIME> accessed 10 July 2024.

CHAPTER 3

I. Transnational Efforts

The transnational regulatory landscape applicable to AI is increasing and numerous soft and hard law instruments recognise the associated risks of AI technologies - though emphasis on environmental sustainability in this context remains uneven.

The OECD AI Principles,[100] adopted in 2019, reviewed in 2024 and endorsed by the G20,[101] serve as a global benchmark for promoting a human-centric approach to AI governance.[102] These principles highlight sustainable development, though primarily in the context of 'AI for sustainability' rather than the 'sustainability of AI'.[103] The Ethics Guidelines for Trustworthy AI, in contrast, emphasise societal and environmental well-being, urging that AI systems be environmentally friendly. The Guiding Principles for AI and a Code of Conduct for AI developers[104] stress identifying and mitigating risks across the entire AI lifecycle[105], although not explicitly referencing environmental risks. All of these instruments remain soft law.

The EU has arguably taken the most comprehensive approach to AI (hard law) regulation.[106] The EU General Data Protection Regulation addresses challenges relating to AI-driven automated

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[100] Forty-two countries adopt new OECD Principles on Artificial Intelligence 2019 <https://www.oecd.org/science/forty-two-coun tries-adopt-new-oecd-principles-on-artificial-intelli gence.htm> accessed 22 August 2024.

[101] *The G20 is an intergovernmental forum consisting of 19 countries and the European Union.* See for example: BBC, 'What is the G20 and what was achieved at the Delhi Summit?' (*BBC*, 11 September 2023) <What is the G20 and what was achieved at the Delhi summit? - BBC News> accessed 23 August 2024.

[102] The OECD Artificial Intelligence (AI) Principles 2019 < https://oecd.ai/en/ai-principles> accessed 22 August 2024.

[103] Principle 1.1 - *'Stakeholders should proactively engage in responsible stewardship of trustworthy AI in pursuit of beneficial outcomes for people and the planet, such as augmenting human capabilities and enhancing creativity, advancing inclusion of underrepresented populations, reducing economic, social, gender and other inequalities, and protecting natural environments, thus invigorating inclusive growth, well-being, sustainable development and environmental sustainability.'*

[104] G7 AI Principles and Code of Conduct 2023 <https://www.ey.com/en_se/ai/g7-ai-principles-and-code-of-conduct> accessed 22 August 2024.

[105] EY, 'News Alert - G7 Principles and Code of Conduct' (*EY*, 31 October 2023) <ey-g7-ai-principles-and-code-of-conduct-final.pdf> accessed 22 August 2024.

[106] EY, 'The Artificial Intelligence (AI) global regulatory landscape - Policy trends and considerations to build confidence in AI' (*EY*, 11 January 2024).

decision making but does not cover environmental protection in the digital sphere.[107] The EU's Digital Services Act[108] governs AI use for online content, while the Cyber Resilience Act[109] offers safeguards against cyber threats. Similarly, the Council of Europe Framework Convention on AI[110] focuses on human rights and ethical principles across the entire AI lifecycle[111] but does not directly address environmental sustainability.

Given this regulatory landscape, the EU AI Act stands out as the most comprehensive approach - addressing the entire lifecycle of systems and associated risk - with the potential to explicitly address environmental protection.

I.I The EU AI Act

The EU AI Act ('**the Act**') represents a significant legislative effort to regulate AI within the European Union. Its final text was passed by the European Parliament on 13 March 2024.[112]

While it emphasises the development and deployment of human-centred and trustworthy AI, its provisions related to environmental protection merit a thorough analysis, particularly as the Act is primarily focussed on consumer protection and product safety. That being said, the Act does not purport to operate in regulatory isolation but alongside other EU law, such as the EU Declaration on Digital Rights and Principles for the Digital Decrease or the Ethics Guidelines for Trustworthy AI.[113]

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[107] Regulation (EU) 2016/679 of The European Parliament and of the Council <https://eur-lex.europa.eu/legal-content/EN/ TXT/?uri=CELEX%3A02016R0679-20160504> accessed 22 August 2024.

[108] The Digital Services Act: ensuring a safe and accountable online environment, EU Commission (EU) 2022/2065, <https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/digital-services-act_en, October 2022> accessed 28 August 2024.

[109] EU Cyber Resilience Act, Shaping Europe's digital future, EU Council (EU) 2019/1020 https://digital-strategy.ec.europa.eu/en/policies/cyber resilience-act, September 2022.

[110] Council of Europe Framework Convention on Artificial Intelligence and Human Rights, Democracy and the Rule of Law <1680afae3c (coe.int)> accessed 22 August 2024.

[111] *See for example, Article 4 relating to the protection of human rights, Article 9 relating to accountability and responsibility and Article 10 relating to equality and non-discrimination.*

[112] Regulation (EU) 2024/1689 of the European Parliament and of the Council of 13 June 2024 laying down harmonised 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).

[113] See Recital 7. *These are both soft law instruments.*

The question, therefore, that this chapter will seek to answer is to what extent the Act contributes to mitigating the environmental impact of AI. In doing so, it will provide an in-depth examination of the Act's provisions and recitals concerning sustainability. As noted by Zuzanna Warso and Kris Shrishak, the EU AI Act focuses more on 'AI for sustainability' rather than the 'sustainability of AI'.[114]

I.I.I Positive Acknowledgement of AI's Benefits

The EU AI Act includes several provisions and recitals that address the potential positive environmental impacts of AI.

- **Recital 4** of the Act explicitly acknowledges that AI can contribute to 'a wide array of economic, environmental, and societal benefits' across 'the entire spectrum of industries and social activities'. Specifically, it highlights the use of AI for environmental monitoring and climate change mitigation and adaptation.
- **Recital 8** notes that the Union framework is needed to promote the adoption and development of AI while ensuring, *i.a.,* the protection of fundamental rights, including environmental protection.
- This acknowledgement is reinforced by **Recital 130**, which emphasises that, in certain situations, the rapid deployment of innovative technologies can be vital for protecting the environment, combating climate change, and benefiting society as a whole.

Despite acknowledging the positive impacts, the Act does not recognise the adverse environmental impacts AI might create. Mention of other adverse impacts of AI is done through **Recital 5** which equally fails to mention harm to the environment, merely 'risks and [...] harm to public interests and fundamental rights protected by Union law'. This omission stands in particular contradiction to the aims of the Act as found in **Recital 1** to ensure 'a high level of protection of health, safety, fundamental rights [...], including democracy, the rule of law and *environmental protection'*.[115]

[114] Zuzana Warso, Kris Shrishak, 'Hope: The AI Act's Approach to Address the Environmental Impact of AI' (*Tech Policy Press*, 21 May 2024) <https://www.techpolicy.press/hope-the-ai-acts-approach-to-address-the-environmental-impact-of-ai/> accessed 1 June 2024.

[115] *(emphasis added).*

I.I.II Environmental Well-being

The above examines to what extent the EU AI Act recognises the negative environmental impacts as it does the positive impacts of AI. In regards to explicit mention of environmental protection in the Act, **Recital 27** provides a notable mention, clarifying that 'social and environmental well-being means AI systems should be *developed* and *used* in a sustainable and environmentally friendly manner [...], while monitoring and assessing the *long-term* impacts on the individual, society and democracy.' This covers both the development and implementation stages of AI but fails to address the entire lifecycle, such as post-use of an AI system. Additionally, it highlights the significance of long-term impacts, extending beyond direct and immediate environmental effects to include impacts that may become apparent at a later stage.

The Act captures this temporal problem of environmental impact further through its emphasis on its ability to dynamically and flexibly adapt 'as technology evolves and new concerning situations emerge.'[116] Such provision may therefore capture emerging environmental concerns.

Indirectly, **Recital 6** states that AI should serve the ultimate aim of increasing human well-being. Given the socio-economic dimension of environmental impacts, one could argue that environmental protection is implicitly contained within the Act's goal of enhancing human well-being. However, the lack of explicit emphasis raises questions about whether environmental protection is indeed implicitly contained within the scope of well-being in the Act. The danger of implying that environmental protection is contained in human well-being lies in the ambiguity and legal uncertainty it creates. It leaves room for interpretation, which can lead to inconsistent applications of the law. Relying on implicit meanings can also weaken enforcement. Therefore, while human well-being might imply a concern for environmental protection, the absence of clear legal language makes its inclusion a contentious point of debate.

[116] 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 Act (2021) <https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex:52021PC0206> accessed 19 August 2024.

I.I.III Environmental Protection as a Fundamental Right?

While environmental protection is mentioned explicitly only a few times throughout the entire Act, fundamental rights are more frequently addressed to justify provisions that limit the development, provision, or use of AI.[117] The question that arises is whether environmental protection is considered a fundamental right under the Act's definition.

Recital 48 provides some insight, stating that 'the fundamental right to a high level of environmental protection enshrined in the Charter[118] and implemented in Union policies should also be considered when assessing the severity of the harm that an AI system can cause, including in relation to the health and safety of persons.' This Recital relates to high-risk AI systems ('**HRAIS**') and their classification, suggesting that AI systems contained within **Annex III** with an adverse impact on environmental protection could be classified as high risk.

Further clarification may be inferred by an official Q&A document - dating prior to the Act being passed - published by the European Commission which notes that the objective of the AI proposal is to address risks to fundamental rights, 'including the fundamental right to a high-level of environmental protection.'[119] The environment is at that point included as one of the protected legal interests. It is not clear, however, whether this statement equally applies post-finalisation of the Act as it did prior to the Act's passing.

I.I.IV Risk-based Approach

The EU AI Act categorises AI systems based on their *intended use*[120] and *technical specifications*.[121] This is supported in **Recital 93** which positively acknowledges that risks may emerge through design and use. As explored above, environmental impact is significantly influenced by the *type of technical system* employed, which affects the computational resources

[117] See Recital 28.
[118] EU Charter of Fundamental Rights.
[119] European Commission, 'Artificial Intelligence - Questions and Answers' (Brussels, 1 August 2024) <QANDA_21_1683_EN.pdf (europa.eu)> accessed 20 July 2024.
[120] Article 3 (12).
[121] Nuno Sousa e Silva, 'The Artificial Intelligence Act: critical overview' (2024) <The Artificial Intelligence Act: critical overview by Nuno Sousa e Silva :: SSRN> accessed 28 August 2024.

required. Additionally, environmental harm can occur *during the use of AI systems*. Therefore, the Act's approach should - at least at surface-level - be suitable to address both design-related and usage-related environmental harm from the outset.

The Act is sector-agnostic and operates through a tiered compliance system[122] - regulating AI systems based on risk with obligations being proportional to the level of risk.[123] The Act broadly introduces two risk categories: prohibited risk and high risk.[124] Compliance obligations depend on the risk category of the AI systems.[125]

However, the categorisation of risk as found in the EU AI Act does not actually fully capture the environmental implications of AI systems, in particular because it focuses on (measurable) risks created by specific applications. By contrast, environmental impact does not solely depend on the use case as defined in **Annex III**; indeed, the most environmentally taxing systems might be categorised as general-purpose models ('**GPAIM**'), which are subject to more lenient requirements under the Act. This can be seen with ChatGPT's models GPT 3.5, GPT 4 or GPT4º[126] (the environmental impact of which is particularly significant) likely being considered GPAIM, or at most GPAIM with systemic risk under the Act.[127] Therefore, increased measures are needed for GPAIM from an environmental protection perspective.

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[122] EY, 'The Artificial Intelligence (AI) global regulatory landscape - Policy trends and considerations to build confidence in AI' (*EY,* 11 January 2024).
[123] Nathalie A. Smuga and Karen Yeung, 'The European Union's AI Act: beyond motherhood and apple pie' (2024) The Cambridge Handbook on the Law, Ethics and Policy of Artificial Intelligence <The European Union's AI Act: beyond motherhood and apple pie? by Nathalie A. Smuha, Karen Yeung :: SSRN> accessed 19 August 2024.
[124] Ibid (n95).
[125] Karen Yeung, Sofia Ranchordas, An Introduction to Law and Regulation (2024, 2nd ed, Cambridge University Press, forthcoming) , Chapter 9, Section 9.2.
[126] Botcampus.ai, 'ChatGPT 3.5 vs ChatGPT 4 vs ChatGPT 4º: A Detailed Comparison' (*Botcampus AI,* 22 May 2024) <ChatGPT 3.5 vs ChatGPT 4 vs ChatGPT 4o: A Detailed Comparison (botcampus.ai)> accessed 21 August 2024.
[127] Article 51; Topics European Parliament, 'EU AI Act: first regulation on artificial intelligence' (8 June 2023) <EU AI Act: first regulation on artificial intelligence | Topics | European Parliament (europa.eu)> accessed 20 August 2024.

I.I.IV.I High Risk AI Systems

There are two identified classes of HRAIS under the Act, namely, AI systems which constitute (safety components) products[128] and those stand-alone systems exhaustively listed in **Annex III**.[129] AI systems deemed high risk under **Annex III** include, *i.a.*, certain biometric identification systems,[130] systems involved in educational or vocational training,[131] or systems involved in law enforcement.[132]

Under the Act, HRAIS are subject to strict obligations and mandatory requirements before they can be offered on the market.[133] However, it is noteworthy that these mandatory requirements for HRAIS do not include any explicit commitments against adverse environmental impacts unless such systems pose a direct threat to *health and safety, or risk adversely impacting fundamental rights*.[134] In this case, providers may conduct a self-assessment prior to placing their system on the market.[135] If they find that their system does not pose such a threat, then they must justify why, even if they are listed in **Annex III**, their system is not a high risk system under the Act.[136]

Essentially, even if an AI system falls under one of the listed use cases, providers would need to disprove that the system does not pose a risk to the health, safety or fundamental rights. If environmental protection is considered a fundamental right under the Act, then systems within **Annex III** that pose a risk to the environment may remain high risk systems and still be subject to stricter requirements. In other words, although the environmental impact does not seem to count much for the definition of what *prima facie* a HRAIS is, it should be taken into account when assessing the exception set forth in **Article 6(4)**.

This categorisation could have commercial implications as a broader range of AI systems would remain under high risk scrutiny due to their environmental impact through the inclusion as a

[128] Article 6(1); Annex I.
[129] Article 6(2).
[130] Annex III (1)(a).
[131] Annex III (3).
[132] Annex III (6).
[133] Articles 9-15.
[134] Article 6(3); *see Recital 48.*
[135] Article 6(4).
[136] ibid.

fundamental right. It still remains unclear as to what the threshold for ‘a significant risk of harm’ under the Act is and clearer definitions are needed to address this for legal certainty and effective implementation.[137] Within the Act’s framework, therefore, referring to fundamental rights is meant to be a form of risk assessment.[138] As most AI systems pose a risk to the environment as outlined above, this would raise the threshold in favour of environmental protection, although the line between *less significant harm* and *significant harm* needs to be navigated.

That being said, as explored in Chapter 2, environmental harm is difficult to quantify due to its multifaceted nature, such as carbon emissions, resource depletion, and water consumption. These environmental impacts are not only difficult to measure but also difficult to standardise across different regions and industries - what may constitute ‘significant risk of harm’ in one context may not be the same in another. Companies may struggle to assess what constitutes ‘significant risk of harm’ which may result in under- or over-compliance. Some companies may be better equipped to make this assessment, while others may struggle (*i.a.* also due to increased costs associated with compliance). Therefore, clear thresholds and measurement criteria are needed.

Furthermore, the Act states that the Commission may adopt delegated acts to amend **Annex III** where the AI systems to be added or modified in the **Annex III**, pose a risk of harm to health and safety, or an adverse impact on fundamental rights.[139] When doing so, the Commission is required to take into account criteria which includes ‘the extent to which the outcome produced involving an AI system is easily corrigible or reversible […] whereby outcomes having an adverse impact on health, safety or fundamental rights, […] are not to be considered’ so.[140] This provision appears to encapsulate the dimension of environmental impact that is both reversible and irreversible, although its effectiveness is somewhat limited by the Act’s consideration of the ‘magnitude and likelihood of benefit of deploying AI systems’ also being a consideration.[141] This implies that the

[137] Article 6(3).
[138] Isabel Kusche, ‘Possible harms of artificial intelligence and the EU AI Act: fundamental rights and risk’ (2024) Journal of Risk Research, 1-4, 6 <Full article: Possible harms of artificial intelligence and the EU AI act: fundamental rights and risk (tandfonline.com)> accessed 1 July 2024.
[139] Article 7(1).
[140] Article 7(2)(i).
[141] Article 7(2)(j).

positive benefits of AI could mitigate its classification as HRAIS, potentially downplaying environmental risks in favour of perceived or actual benefits.

The Commission is tasked with issuing standardisation requests, seeking deliverables on reporting and documentation, including enhancements in AI systems' resource performance.[142] This includes reducing the energy and resource consumption of HRAIS throughout their lifecycle and promoting energy-efficient development of GPAIM.[143] The wording 'such as' does not limit the focus to energy consumption alone, as does the mention of 'other resources' which both allow for the inclusion of other environmental impacts, such as water usage and indirect effects. However, the primary emphasis remains on energy consumption.

In regards to the standardisation process itself, there is no set timeframe by which these standards must be produced by the EU standardisation bodies. While the EU Commission has adopted an official standardisation request in May 2023,[144] a request for GPAIM has not been drafted yet.[145] Greater clarity is needed in this regard as to when a similar standardisation request will be made or when they might be published in the EU's Official Journal.[146]

Moreover, it has been argued that relying on standardisation bodies to develop these standards could be time-consuming, potentially delaying implementation.[147] Nevertheless, if effectively enforced, these standards could significantly reduce AI's resource consumption. It is important to note that this provision applies only to HRAIS and not to GPAIM. By restricting the provision to HRAIS, the Act misses an opportunity to comprehensively monitor and control the broader resource consumption of AI technologies. Expanding the scope to include GPAIM could lead to

[142] Article 40(2).
[143] Article 40(2).
[144] Hadrien Pouget, 'Standard Setting' (*EU Artificial Intelligence Act*) <Standard Setting | EU Artificial Intelligence Act> accessed 20 August 2024.
[145] ibid.
[146] Jimmy Farrell, 'An introduction to Codes of Practice for the AI Act' (*EU Artificial Intelligence Act*, 3 July 2024) <An introduction to Codes of Practice for the AI Act | EU Artificial Intelligence Act> accessed 20 August 2024.
[147] José Renato Laranjeira de Pereira, 'The EU AI Act and environmental protection: the case for a missed opportunity' (Boell, 8 April 2024) <The EU AI Act and environmental protection: the case for a missed opportunity | Heinrich Böll Stiftung | Brussels office - European Union (boell.org)> accessed 20 August 2024.

more effective oversight and reduction of the environmental impact of all AI systems, not just those classified as high risk.

I.I.IV.II Fundamental Rights Impact Assessments

For certain AI systems classified as HRAIS under the Act, **Article 27** mandates a Fundamental Rights Impact Assessment ('**FRIA**'). This requirement essentially entails an evaluation on how AI systems might affect fundamental rights. The primary objective of the FRIA is to identify and mitigate potential harms to these rights posed by HRAIS.[148]

While the inclusion of the FRIA is a commendable provision that goes beyond mere technical compliance - being the first of its kind in the context of fundamental rights[149] - ambiguity remains as to whether all or just some specific fundamental rights are covered by the assessment.[150] Although environmental protection is recognised as a fundamental right under the EU Charter of Fundamental Rights,[151] it is unclear whether this right is encompassed within the scope of the FRIA. Clarifying this inclusion would mark a significant advancement towards enhancing the sustainability of AI systems, as it would necessitate a thorough evaluation of environmental risks prior to deployment. That being said, the Act does impose a requirement on the AI Office to develop a questionnaire for a simplified completion of the assessment which may eventually contribute to clarifying the provisions' scope.[152]

From a commercial perspective, conducting a FRIA requires an extensive understanding of fundamental rights law to assess compliance with the Act's provisions.[153] This requirement would

[148] Recital 96.
[149] Thibaut D'hulst, 'Fundamental Rights Impact Assessment under the EU AI Act' (*Lexology*, 28 March 2024) <Fundamental Rights Impact Assessment under EU AI Act - Lexology> accessed 21 August 2024.
[150] *The fundamental rights enshrined in the Charter of Fundamental Rights are extensive and supplemented by case-law from the Court of Justice of the EU and the EU Court of Human Rights*. Heidi Waem, Jeanne Dauzier, Muhammed Demircan , 'Fundamental Rights Impact Assessments under the EU AI Act: Who, what and how?' (*DLA Piper*, 7 March 2024) <Fundamental Rights Impact Assessments under the EU AI Act: Who, what and how? | Technology's Legal Edge (technologyslegaledge.com)> accessed 31 August 2024.
[151] Article 37, 'A high level of environmental protection and the improvement of the quality of the environment must be integrated into the policies of the Union and ensured in accordance with the principle of sustainable development.'
[152] Article 27(5).
[153] ibid (n150).

pose a challenge for small and medium-sized companies (‘**SMEs**’) and startups, which may lack the necessary legal expertise and resources.

A comprehensive FRIA should include an assessment of ‘specific risks of harm likely to impact categories of natural persons’ and outline measures to mitigate those risks - so, essentially consisting of a description, assessment of risks involved and affected groups of individuals and risk mitigation measures.[154] Notably, the FRIA is only required for the initial deployment of an HRAIS.[155] In practice, this may prove difficult - not all environmental impacts may be known prior to deployment, such as those dimensions of impact that may be delayed-onset, cumulative or widespread. Deployers may need to consider ongoing risks that could arise not only from the design of the AI system but also from its use, including the different dimensions to environmental impacts.

By ensuring that environmental protection is explicitly included under the scope of the FRIA, the EU AI Act could significantly enhance the sustainability of AI systems. This approach would foster a more holistic evaluation of the risks and benefits associated with AI deployment, promoting responsible innovation while safeguarding fundamental rights and environmental integrity.

I.I.IV.III Reporting of Serious Incidents

Article 3(49) defines a serious incident as a malfunctioning of an AI systems which *directly* or *indirectly* results in, *i.a.*, serious harm to a person’s health,[156] or serious harm to property or the environment.[157] **Article 73** specifies the reporting obligations for such incidents, requiring providers of HRAIS to notify the competent authorities.[158] This notification must occur ‘immediately after the provider has established a causal link’ between the AI systems and the

[154] Article 27 (1)(f).
[155] Recital 96.
[156] Article 3(49)(a).
[157] Article 3(49)(d).
[158] Article 73(1).

incident, or when there is a reasonable probability of such a link.[159] In any case, the report must be submitted no later than 15 days after the provider becomes aware of the incident.[160]

From an environmental protection perspective, these reporting requirements raise important considerations. Firstly, they only apply to HRAIS which again omits those systems not categorised as such. While environmental harm is explicitly recognised as a serious incident, in practice, identifying and attributing such harm can be far more complex than other types of damage, i.e. harm to property. As discussed in Chapter 2, environmental harm can be cumulative, arising in combination with other forms of damage. It can also be delayed, making it difficult to establish a clear temporal link between the harm and the AI system's malfunction. Additionally, environmental damage might be widespread and diffuse, making it hard to trace back to a single provider of location.

It may also be difficult to trace environmental impact to one single provider - and therefore, such reporting would only be limited to those impacts directly and feasibly attributable to a provider, disregarding other impacts.

In contrast to property damage, which tends to be more immediately identifiable and tangible, environmental harm can remain subtle and latent for long periods. Therefore, unless the environmental damage is obvious and direct, it may evade detection under the current reporting framework.

I.I.IV.IV Codes of Conduct

Other provisions, such as **Article 95**, refer to voluntary measures only through codes of conduct. Under the Act, the AI Office and Member States are to draw up codes of conduct, which include elements such as assessing and minimising the impact on environmental sustainability, again, focusing explicitly on energy-efficient programming and techniques, disregarding other impacts that may arise.[161]

[159] Article 73(2).
[160] Article 73(2).
[161] Article 95(2).

Although, there is explicit mention of environmental sustainability, this occurs in a voluntary context. Nevertheless, there is differentiation within this Article of the different lifecycle stages of AI - referring to ‘efficient design, training and use of AI’.[162]

The voluntary nature of the codes means that there may be insufficient incentives for their implementation - with such measures relying on goodwill.[163] Research suggests that compliance with voluntary measures as instated under EU law have low implementation rates - with too little perceived incentive for developers, providers and deployers to implement these measures.[164] Voluntary measures cannot stand in isolation but must be complemented by legally binding measures that sufficiently address environmental impacts.[165]

I.I.IV.V General Purpose AI Models

What if an AI system is not classified as high risk under the Act? The Act provides for two categories of note due to the obligations they seek to impose, namely, GPAIM[166] and GPAIM with systemic risk.[167] At this stage, it is important to note that the Act acknowledges that an AI model is not in itself an AI system, but rather incorporated into an AI system (a component thereof).[168] GPAIM - as models - are not regarded as being HRAIS - as systems.[169] This is why the sub-classification of GPAIM with systemic risk was introduced.

Classification as a GPAIM with systemic risk, according to current technological standards,[170] depends on whether the GPAIM matches or exceeds the computation threshold of 10(^25) Floating

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[162] Article 95(2)(b).

[163] Kate Crawford, ‘Generative AI’s environmental costs are soaring - and mostly secret’ (*Nature*, 20 February 2024) <Generative AI’s environmental costs are soaring — and mostly secret (nature.com)> accessed 24 August 2024.

[164] Helen Keller, ‘Codes of Conduct and their Implementation: the Question of Legitimacy’ in Rüdiger Wolfrum, Volker Roeben, *Legitimacy in International Law* (Springer, 2008) 291.

[165] ibid (n77).

[166] Article 51.

[167] Article 55.

[168] Epstein Rosenblim Maoz, ‘How General Purpose AI (GPAI) models are regulated under the new Act on Artificial Intelligence (AI Act)’ (*ERM*, 4 March 2024) < How General Purpose AI (GPAI) models are regulated under the new Act on Artificial Intelligence (AI Act) - Epstein Rosenblum Maoz (ERM) (erm-law.com)> accessed 21 August 2024.

[169] ibid.

[170] *Article 51(3) provides that this threshold might change depending on tech developments.*

Point Operations per Second ('**FLOPS**') during training. GPAIM matching or surpassing this threshold are *presumed* to have high impact capabilities.[171] However, this presumption is rebuttable, meaning that even systems trained on significantly higher FLOPS, such as 10(^30), may still avoid this classification under certain circumstances.[172]

If an AI system is classified as a GPAIM with systemic risk, its providers and deployers are subject to specific regulatory requirements. These requirements, however, do not include environmental obligations, and therefore do not warrant further analysis in this context. The appropriateness of using FLOPS as a metric will be explored in greater detail in the next chapter.

Classification as a GPAIM without systemic risk carries few requirements although mostly voluntary measures.[173] Most notably, the AI Office should 'encourage' the development of codes of practice and 'invite' providers of GPAIM to implement these. It is explicitly stated that providers of GPAI need not comply with the full code but may do so if they wish to.[174]

Whether classified as a GPAIM with systemic risk or a GPAIM without systemic risk, providers of AI systems, pursuant to **Recital 65,** should merely be 'encouraged' to create their own codes of conduct to promote the 'voluntary application' of 'some or all' of the mandatory requirements which apply to HRAIS. It is questionable whether such codes of conduct are effective in achieving their aims - with previous codes of conduct as mandated by EU law proving somewhat ineffective.[175]

I.I.V Balancing Regulation with Innovation and Competition

The Act aims to balance stringent regulation with the promotion of innovation and competition within the AI sector. This balance is clear in various articles and recitals throughout the Act,

[171] Article 51(2).
[172] ibid (n121) 33.
[173] See for example Article 56.
[174] Article 56(7).
[175] See the Code of Practice on Disinformation. <EU Code of Practice on Disinformation | European Commission (europa.eu)> accessed 30 July 2024.

reflecting the EU's commitment to technological advancement while ensuring a competitive environment:

- **Article 2** clarifies that regulation does not apply to scientific development and innovation.
- **Recital 8** further notes that a Union legal framework is necessary to foster the development, use, and uptake of AI in the internal market while simultaneously ensuring a high level of protection of public interests, including environmental protection.
- **Recital 2** reinforces this by stating that the regulation should support innovation and environmental protection.

Chapter VI of the Act outlines measures that support innovation through AI regulatory sandboxes. These sandboxes provide a controlled environment for testing and developing AI systems under regulatory supervision, enhancing legal certainty for innovators and accelerating market access. **Recital 138** specifically calls for Member States to establish at least one AI regulatory sandbox to support this goal. In general, these sandboxes can provide insight into the environmental impacts of the system being employed and inform future regulatory approaches according to the tools' aim of 'develop first, learn about the effects, then develop regulation.'[176]

Additionally, **Recital 142** encourages the promotion of R&D solutions that deliver socially and environmentally beneficial outcomes, including meeting environmental targets. This provision underscores the Act's objective of balancing innovation with the need for robust environmental protection.

As will be discussed in the following, the Act's consideration of interests (such as competition and innovation) helps to strike a balance between protection from the risks of AI without stifling innovation and competition, which in turn might provide positive environmental impact.

[176] Bárbara Jennifer Paz, Kai-Fu Lee, 'AI Superpowers: China, Silicon Valley, and the New World Order' (2020) 35 AI & Soc, 771-772 <Kai-Fu-Lee (2019): AI Superpowers—China, Silicon Valley and the New World Order | AI & SOCIETY (springer.com)> accessed 5 July 2024.

I.I.VI Is the EU AI Act the right instrument to address the environmental impact of AI?

It is clear that the EU AI Act does not adequately address the full scope of AI's environmental impact. However, the question remains whether the EU AI Act is even the appropriate instrument to regulate these environmental concerns. This thesis argues in favour of this approach, with the caveat that this should be reevaluated as more data becomes available through enhanced reporting and transparency. Once the environmental impact of AI, and associated technologies, is more comprehensively known, there may be merit in considering a standalone regulatory framework dedicated to these issues.

Firstly, the aim of the Act is to address the unique characteristics and risks associated with AI systems while safeguarding fundamental rights outlined in the Charter, including environmental protection.[177] As such, the Act's core purpose inherently includes environmental protection, positioning it as a suitable framework for integrating additional measures at the purpose level.

Although environmental impacts of compute extend beyond AI, they do manifest at system-level as well. This alignment with system-level (and multiple design-level) risks makes the AI Act an appropriate tool in this context. Its flexible and adaptable design, intended to be future-proof, further enhances its ability to accommodate emerging environmental concerns.

The Act is fundamentally centred around risk of AI, including provisions for identifying and mitigating risks, which makes it possible to incorporate environmental risks. By expanding its scope, the Act could also address the multi-faceted impacts of AI systems, ensuring they align with broader sustainability goals.

As a sector-agnostic regulation, the AI Act applies across all industries, considers many different sources of risk, and safeguards most fundamental rights. Other regulatory instruments may focus on one particular risk and fundamental right, such as data protection in the EU GDPR. Therefore,

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[177] Recital 1.

such instruments would not fully capture the broad and interconnected nature of AI's environmental impact. The Act works in tandem with other regulatory instruments, such as the Charter of Fundamental Rights. Such soft law instruments provide foundational principles but they do not offer the specific, actionable requirements needed to regulate AI's environmental impact. The Act, however, is designed to be enforceable, with clear provisions, and oversight mechanisms.

Moreover, the Act already considers various competing interests, such as fostering innovation, ensuring public safety, and maintaining fair competition. These considerations are crucial when regulating environmental risks, as they require a balanced approach that does not stifle technological progress. The Act's framework, which includes differential obligations for SMEs and startups can be adapted to address the challenge of balancing environmental protection with these other interests.

However, legitimate concerns exist regarding the AI Act's capacity to take on the additional responsibility of regulating environmental impacts without overextending its scope. Expanding the Act's remit could complicate its implementation and potentially dilute its effectiveness in managing core risks it was originally designed to address. On the other hand, creating a separate regulatory instrument dedicated to AI's environmental impact risks further fragmenting the legislative landscape and complicating efforts. This could lead to inefficiencies and overlaps between regulatory frameworks, ultimately undermining the goals of cohesive and effective regulation. As such, the next chapter discusses regulatory proposals aimed at amending the AI Act with the purpose of improving its effectiveness in addressing the environmental impact created by AI.

II. Summary

This EU AI Act is a significant legislative step toward regulating AI at transnational level, balancing innovation, consumer protection, and fundamental rights. However, it falls short in addressing AI's negative environmental impacts comprehensively.

While the Act highlights AI's positive environmental role, such as in climate change mitigation, it lacks focus in regards to the sustainability of AI, particularly in managing its lifecycle environmental impacts, including post-use.

The Act does reference environmental protection in some contexts, linking it to HRAIS that could harm health and safety, and the Charter of Fundamental Rights is intended to be read in tandem with the EU AI Act. However, it remains unclear whether environmental protection is consistently treated as a fundamental right, potentially complicating enforcement.

The Act's risk-based approach classifies AI systems by potential harm but does not fully account for environmental implications across all systems. GPAIM may escape stricter scrutiny despite their potentially significant environmental impact. Additionally, it is ambiguous whether environmental protection is explicitly covered in FRIA for HRAIS.

Voluntary measures, like codes of conduct, aim to promote sustainability, but their non-binding nature raises doubts about their effectiveness. Historically, voluntary compliance under EU law has faced challenges, suggesting the need for stronger, binding environmental protections.

Though the Act seeks to balance regulation with innovation, its reliance on voluntary standards, particularly for GPAIM, overlooks opportunities for comprehensive environmental oversight. AI regulatory sandboxes could help assess environmental impacts, but stronger mechanisms are needed to ensure AI development doesn't compromise environmental integrity.

In conclusion, the EU AI Act does little to contribute to the mitigation of AI's multi-faceted environmental impact - more explicit and binding provisions are needed to effectively address the environmental risks posed by AI technologies.

I. Regulatory Proposals

Previous chapters have highlighted the environmental impact of AI and associated compute and analysed the EU AI Act in addressing these impacts - identifying gaps in the current regulatory provision. This chapter aims to provide recommendations as to how these regulatory gaps may be filled. The accompanying Annex touches on the preliminary discussion on regulatory challenges and available tools which can be referred to prior to the suggested proposals for increased context.[178]

II. Part One: Regulating (AI) Compute

II.I Why regulate (AI) Compute?

As the data in Chapter 2 suggests, an adverse environmental impact is not an 'AI problem' but rather a 'compute problem.' Compute can be divided into three areas which converge with one another - compute for AI; compute for modelling and simulation; and cloud computing.[179] The following will refer to AI compute, defined by the OECD Expert Group as '[...] resources which include one or more stacks of hardware and software used to support specialised AI workloads and applications in an efficient manner.'[180]

The following will divide compute into three categories: hardware, infrastructure and resources. Examples of AI hardware components, without delving into technical details, include the chips necessary to operate the AI, such as GPUs and Field Programmable Gate Arrays ('**FPGAs**') which

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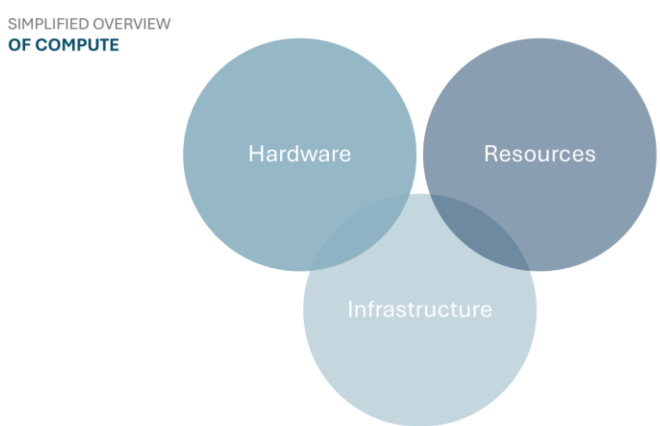
[178] *The regulatory priorities identified do not claim to be an exhaustive list.*
[179] Gov.UK, 'Independent Review of the Future of Compute' (*Gov.UK*, 13 June 2022) <Independent Review of The Future of Compute: Final report and recommendations - GOV.UK (www.gov.uk)> accessed 29 July 2024.
[180] ibid (n53) 5.

are used during the inference stage.[181] AI-specific hardware, like GPUs and FGPAs[182] are associated with AI models (such as NLPs, DNNs, and ML algorithms) that create significant environmental impacts. Regulating AI hardware targets these high-impact (frontier) models without imposing unnecessary restrictions on general computing hardware, which may be less environmentally taxing.

Computing resources refers to the availability and capacity of the hardware to process the data, run algorithms, and perform AI tasks.[183] The amount of compute is often quantified by the number of operations per second, such as through FLOPS that the hardware can perform.[184]

Infrastructure includes the data centres, servers and cloud-based systems where the AI hardware operates. It is the environment through which the hardware can function.[185]



**Note: This is a simplified overview of compute to limit the scope of this thesis.*

[181] Editorial, 'AI Hardware - What They Are and Why They Matter in 2023 (Updated)' (Roboticsbiz, 3 January 2021) < AI hardware - What they are and why they matter in 2023 [Updated] (roboticsbiz.com)> accessed 18 July 2024.
[182] *Such as AI-specific chips - using general-purpose chips in the context of AI would take longer and increase costs substantially.*
[183] AWS, 'What is Compute' (AWS) <https://aws.amazon.com/what-is/compute/#:~:text=Compute%20resources%20are%20measurable%20quantities%20of%20compute%20power,be%20requested%2C%20allocated%2C%20and%20consumed%20for%20computing%20activities.> accessed 24 August 2024.
[184] See EU AI Act or U.S. Executive Order (E.O.) 14110 on the Safe, Secure, and Trustworthy Development and Use of Artificial Intelligence.
[185] Clive Longbottom, Stephen J.Bigelow, 'Definition: Infrastructure (IT Infrastructure)' (TechTarget) <What is infrastructure (IT infrastructure)? | Definition from TechTarget> accessed 24 August 2024.

While the full extent of AI's environmental impact is unknown, the impact of certain AI hardware, such as data centres and GPUs, is clearer. Regulating compute offers a practical approach, as it is 'detectable, excludable, quantifiable and produced via an extremely concentrated supply chain' whereas regulating AI systems is more challenging as AI, such as algorithms and data, is intangible.[186]

Heim et al. provides an extensive analysis on why compute should be targeted by regulation, arguing firstly that compute is quantifiable to the extent that consumption can be measured, such as through floating point operations as has been used in the EU AI Act.[187] Quantifiability is also important as it allows differentiation, which as aforementioned fosters an innovative and competitive environment in favour of SMEs and startups, as opposed to blanket regulation. Regulation would not seek to simply stop certain operations but limit them according to defined thresholds. As has been concluded above, the higher the computational resources, the greater the impact on the environment. This is also helpful as quantifiability allows for easier monitoring and assessment of what environmental resources the hardware requires. This, of course, must be accompanied with requirements to monitor and disclose such insight in a secure way which informs rather than gives away competitive interests.

Compute is also detectable and tangible[188] - which combined with the highly concentrated supply chain of compute,[189] provides ideal conditions for targeted excludability and allows for differentiation. It is clear that only major companies, such as those termed the 'hyperscalers' consisting of Amazon, Google and Microsoft, are able to afford the production and provision costs of compute.[190] The company Nvidia is considered the world's largest manufacturer of chips used

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[186] Lennart Heim, Markus Anderljung, and Haydn Belfield, 'To Govern AI, We Must Govern Compute' (CNAS, 28 March 2024) <To Govern AI, We Must Govern Compute | Center for a New American Security (en-US) (cnas.org)> accessed 30 July 2024.
[187] *Additional requirements for foundation models trained on more than 10(^25) operations.*
[188] ibid (n186).
[189] ibid (n186).
[190] Fred Lewsay, 'Artificial Intelligence: Aim policies at 'hardware' to ensure AI safety, say experts' (University of Cambridge, 14 February 2024) < Artificial intelligence: Aim policies at 'hardware' to ensure AI safety, say experts - Bennett Institute for Public Policy (*cam.ac.uk*)> accessed 29 July 2024.

for AI and computer graphics, with roughly 80% of market share.[191] This is in contrast to the challenges of regulating more intangible features of AI, such as data or algorithms.

Despite these benefits, it is important to consider the disadvantages that come with regulating compute. Increased disclosure through better quantifiability may increase cybersecurity risks - including risks of leakage of sensitive information. These risks may be mitigated through greater cybersecurity and privacy guardrails.

Additionally, the 'pacing problem' increases, with more specific regulation. Specifying thresholds for compute may result in regulation becoming outdated faster. However, it can be argued that a certain degree of specificity is required in order to balance innovation with environmental regulation. From an environmental impact perspective, hardware-specific regulation can also address the varying environmental footprints that different components may have. It is becoming increasingly evident that regulations tied to technology must be continuously reviewed - this is an unavoidable reality. Embracing this necessity allows us to leverage the benefits that greater specificity can offer, particularly in terms of environmental impact.

Lastly, over-regulating specific AI hardware could inadvertently create significant bottlenecks across the entire AI value chain. Such constraints may stifle innovation and slow down the deployment of AI systems, leading to economic disadvantages that reverberate through various industries. These bottlenecks could result in higher production costs, which, in turn, would drive up the prices of AI products and services. Consequently, increased costs would likely be passed on to consumers, ultimately inhibiting access to advanced AI technologies for both businesses and individuals. Restrictive regulations could also deter investments. Impacts may also extend beyond higher production and deployment costs, it may deter AI research and development, hampering competitiveness. AI hardware manufacturers may relocate operations to less regulated regions. These potential risks associated with over-regulation require a balanced and collaborative approach that is proportional and informed.

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[191] Foo Yun Chee 'EU, Chinese, French regulators seeking info on graphic cards, Nvidia says' (*Reuters*, 24 November 2023) <EU, Chinese, French regulators seeking info on graphic cards, Nvidia says | Reuters> accessed 24 July 2024.

II.II How might regulating (AI) compute look in Practice?

1. Regulating Hardware

One example of hardware regulation is the regulation of GPUs. While national regulations, such as the China Energy Label,[192] which mandates GPUs to display energy efficiency ratings, are steps in the right direction, they primarily focus on energy consumption and GHG emissions. However, the impact of hardware extends beyond these aspects. For instance, GPUs involve complex manufacturing processes that are both mineral- and water-intensive.[193]

GPUs have also been regulated in a non-environmental law context in the U.S which imposed restriction in relation to export in an effort to make the chips more inaccessible to Chinese markets.[194] These restrictions illustrate how hardware has and can be regulated. It has been highlighted that being able to accurately measure the performance of different AI hardware can help drive forward sustainability.[195]

Voluntary certification marks may also be an option, albeit not a legally binding option in promoting the sustainability of hardware. Existing certification schemes from the World Wildlife Fund ('**WWF**')[196] and Fairtrade[197] are typically associated with sustainability in areas, such as consumer goods, agriculture or fishing. However, such schemes may be adapted to hardware. Fairtrade's focus on ethical sourcing may be replicated to ensure that materials used in the production of components are sourced responsibly. This could include ensuring mining practices do not violate environmental or human rights.[198]

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[192] Gogyi Zhang, Chang Zhang, and Hongguang Nie, 'An Overview of China's Energy Labeling Policy Portfolio: China's Contribution to Addressing the Global Goal of Sustainable Development' (2021) 11 Sage Open 1.

[193] Marcello Ruberti, 'The chip manufacturing industry: Environmental impacts and eco-efficiency analysis' (2023) 858 Science of the Total Environment 2.

[194] ibid (n190).

[195] Nature, 'AI hardware has an energy problem' (Nature, 26 July 2023) <s41928-023-01014-x.pdf (*nature.com*)> accessed 24 August 2024; Nathaniel Joseph Tye, Stephan Hofmann, Phillip Stanley-Marbell, 'Materials and devices as solutions to computational problems in machine learning' (2023) 6 Nature Electronics, 479.

[196] *See WWF's certification schemes, including Forest Stewardship Council, Roundtable on Sustainable Palm Oil, Bonsucro, Global Roundtable for Sustainable Beef, Roundtable on Sustainable Biomaterials*; WWF, 'Certification and roundtables: do they work' (*WWF*, 2010) <wwf_certification_and_roundtables_briefing.pdf> accessed 28 August 2024.

[197] *See <Why partner with Fairtrade - Fairtrade> accessed 28 August 2024.*

[198] *This would also address indirect environmental impacts as outlined in Chapter 2.*

WWF promotes practices to reduce environmental impacts, which could equally be applied to ensure that AI hardware manufacturers use renewable energy in their production. Components may be certified on the basis of their carbon footprint, similar to energy efficiency labels outlined above. Certification may also occur to uphold social standards addressing indirect environmental impacts at component-level.

Environmental Measures Beyond Energy Consumption and GHG Emissions

To address these broader environmental challenges, regulations could include:

- Responsible sourcing of materials
- Limits on water consumption
- Energy efficiency requirements
- E-waste management

In implementing these regulations, a combination of CAC approaches and MBIs can be effective. CAC approaches can establish baseline environmental standards for all types of hardware, including both AI-specific chips like GPUs and more general compute hardware. These standards could include mandatory energy efficiency requirements. However, overly stringent CAC regulations could potentially stifle innovation and/or increase costs, particularly in a rapidly evolving field like AI hardware.

To balance this, MBIs could be employed to incentivise companies to innovate towards more sustainable hardware solutions. Tax credits or subsidies could be offered to manufacturers that develop GPUs or other chips with higher performance per watt. These incentives would encourage companies to voluntarily exceed baseline environmental standards, fostering innovation and ensuring innovators reap the benefits thereof.

It must be noted that in order to effectively navigate these targeted measures, entities within the AI hardware ecosystem require support in understanding the environmental impacts of their hardware. One potential solution is the promotion of regulatory sandboxes at component-level -

controlled environments where companies can experiment with new technologies without the full burden of regulatory compliance. These sandboxes would allow hardware developers to explore innovative solutions for reducing environmental impacts, such as more efficient materials, or new manufacturing processes. They would also foster collaboration between companies and regulatory bodies, enabling a better understanding of the challenges and opportunities in making hardware more sustainable.

Environmental Impact Assessments for Hardware

A critical component of ensuring the environmental sustainability of AI hardware is the implementation of mandatory Environmental Impact Assessments ('**EIAs**') for hardware developers and producers. EIAs are already a standard requirement in the EU for major construction and development projects,[199] where they assess potential environmental impacts before a project begins. These assessments lead to the creation of Environmental Impact Statements, which could serve as a valuable framework when applied to the AI and compute sectors, as they evaluate effects on land, soil, water, air, climate and other environmental factors.[200]

Traditionally, EIAs are preventative tools, meaning they must be completed before a project receives development approval. However, in the context of hardware, while it is important not to hinder innovation and competition, EIAs could be adapted to function as sustainability tools. Instead of being a prerequisite for development, the assessments could be used to set benchmarks for improvement, driving sustainability without imposing rigid barriers. It is, however, crucial that these assessments are mandatory and sufficient guidance as to how such reporting should be conducted is given.

The scope of such EIAs would need careful consideration to determine which manufacturers, if not all, should be subject to these assessments. Tailoring the EIA requirements to the specific environmental risks associated with hardware production will ensure that they are both effective and fair.

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[199] (EIA) Directive (2011/92/EU as amended by 2014/52/EU).

[200] European Commission, 'Environmental Impact Assessment - evaluating the effect of public and private projects on the environment' (EU Commission) < Environmental Impact Assessment - European Commission (europa.eu)> accessed 23 August 2024.

Increased transparency and data on the most resource-intensive hardware would allow for a more targeted regulatory approach. These assessments should evaluate the full lifecycle impact of hardware components - from raw material extraction and manufacturing to operation and end-of-life disposal. These assessments would provide a comprehensive understanding of the environmental risks associated with hardware production. The *quality* of reporting should be considered to ensure that reporting is not only done but done in a valuable way.[201]

To ensure impartiality, the assessments would ideally be conducted or verified by independent third-party organisations accredited by regulatory bodies. The results should be disclosed to relevant regulatory bodies and/or to the public in a standardised format, allowing for comparison across different manufacturers.

The data gathered through EIAs should also be passed systematically along the supply chain - from hardware producers to developers and deployers. This would ensure that each actor in the AI ecosystem is aware of the environmental footprint of the hardware they use and can take appropriate measures to mitigate this impact. For instance, AI developers could use EIA data to optimise their systems for energy efficiency and minimal resource use, aligning their operations with broader sustainability goals. To mitigate data security concerns, support should be given to help institutions improve their reporting capability, including secure data collection.[202]

Alternatively, such efforts may be integrated in the EU's Corporate Sustainability Reporting Directive[203] ('**CSRD**') which requires large companies and listed companies to publish regular reports on the social and environmental risks involved in their operations. Although, compared to EIAs, they focus on disclosure and reporting and influences the companies' ESG standing - this directive does not impose substantive obligations on companies to achieve certain environmental

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[201] *See challenges banks have faced through increase regulatory reporting requirements: Deloitte, 'How banks can derive benefits from increasing regulatory reporting requirements' (Deloitte, 13 October 2023) <How banks can derive benefits from increasing regulatory reporting requirements | Deloitte UK> accessed 24 August 2024.*

[202] PwC, 'Sustainability reporting in 2024' (*PwC*) <Sustainability reporting in 2024: what's coming, and the actions you can take now - PwC UK> accessed 24 August 2024.

[203] (EU) 2022/2464 Directive.

outcomes. Data centre operators and entities that run their own data centres would fall within the scope of this directive.[204]

It is important to note that irrespective of the form reporting requirements take, positive environmental impact must also be reflected alongside negative environmental impacts - this would ensure a balanced and proportionate assessment.

Integrating EIAs into Broader Regulatory Frameworks

The information disclosed through EIAs should not exist in isolation but must be integrated into broader regulatory frameworks that govern AI systems - such as the EU AI Act. This approach will be discussed in more detail in the following section exploring system-level regulation through amendments to the EU AI Act.

2. Regulating Resources

One way to regulate compute resources is through Floating Point Operations per Second ('**FLOPS**'). This metric represents the number of floating point calculations a system can perform per second, making it a useful, though limited, proxy for the resources consumed during AI model training.

This has been previously done in the United States through the introduction of the Executive Order on the Safe, Secure, and Trustworthy Development and Use of AI.[205] This order mandates compliance for AI models trained using significant computational power, defined as models using over 10(^26) FLOPS[206] or those primarily involving biological sequence data requiring more than

[204] Venessa Moffat, 'Data Centre Sustainability Regulation: The timeline that requires immediate action' (*Techerati*, 14 November 2023) <Data Centre Sustainability Regulation: The timeline that requires immediate action - Techerati> accessed 23 August 2024.
[205] U.S Executive Order (E.O) 14110 on the Safe, Secure, and Trustworthy Development and Use of Artificial Intelligence (WH.Gov, 30 October 2023) <Executive Order on the Safe, Secure, and Trustworthy Development and Use of Artificial Intelligence | The White House> accessed 24 August 2024.
[206] Para 4.2 (b)(i).

10(^23) FLOPS.[207] The order emphasised the need for technical conditions to identify models with potential for malicious cyber-enabled activities.

The EU AI Act, as discussed above, also adopts FLOPS as a metric.[208] These thresholds illustrate that using FLOPS as a proxy for model capabilities has been implemented at both transnational and national levels.

However, this metric does have its limitations and should be carefully considered if used in the context of environmental regulation. While it is quantifiable and measurable, computational power is just one aspect of AI training and may overlook other aspects, such as the quality of training data. For example, a model might expend the same number of FLOPS on poor quality training data, resulting in an inferior model, while less but higher quality data could produce a better performing model with fewer computational resources.[209] Additional metrics might need to be integrated where appropriate to account for data quality.

To be used in this context, appropriate thresholds need to be set to ensure that only the most resource-intensive models are subject to stringent environmental regulations. These thresholds need to be reviewed and improved, as hardware becomes more efficient (also seen in the EU AI Act).[210] Integrating FLOPS into regulation is a highly technical approach which requires collaboration with technology experts in designing the parameters of such regulations.

Models falling below thresholds should not be exempt from all environmental obligations. A balanced approach is necessary to avoid imposing unnecessarily high burdens on all computational processes, particularly for startups and SMEs. The U.S approach may provide regulatory inspiration on this point. However, given the concentration of power in the AI supply chain, this

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[207] ibid.

[208] *The Act defines FLOPS in Article 3(67) as 'any mathematical operation or assignment involving floating-point numbers, which are a subset of the real number typically represented on computers by an integer of fixed precision scaled by an integer exponent of a fixed base.'*

[209] Enterprise Big Data Framework, 'Understanding Data Quality- Ensuring Accuracy, Reliability, and Consistency' (Enterprise Big Data Framework, 16 July 2024) <Understanding Data Quality: Accuracy, Reliability, and Consistency (bigdataframework.org)> accessed 24 August 2024.

[210] Article 51(3); Recital 111.

targeted regulation may automatically target those entities with higher resources to accommodate higher environmental standards.

While FLOPS may be a useful metric for regulating environmental impact as extensive computational resources (higher FLOPS) are worse from an environmental perspective, its application in other regulatory contexts, such as preventing malicious uses of AI has been criticised.

3. Regulating Infrastructure

Regulating the infrastructure that supports AI compute, such as data centres and cloud computing facilities, is essential for minimising the environmental impact of (AI) technologies. Infrastructure regulation should focus on improving the energy efficiency and sustainability of the physical spaces where compute takes place, given that data centres are a significant source of energy consumption and carbon emissions.

Existing supranational approaches exist which attempt to make compute more efficient and sustainable. Notably, the European Code of Conduct for Data Centre Energy Efficiency ('**EU DC CoC**')[211] is a voluntary initiative encouraging data centre operators to adopt best practices that reduce environmental impact. It uses Power Utilisation Effectiveness ('**PUE**') as a key metric to assess the overall efficiency of a data centre, with a lower PUE indicating a more efficient facility. While the EU DC CoC serves as a foundational framework, its voluntary nature limits its impact, especially given the urgent climate challenges we face.

The Ecodesign Requirements on servers and data storage products[212] further complements these efforts by setting mandatory requirements for energy efficiency[213] and material resource efficiency,[214] ensuring that new servers and data storage products are designed with sustainability

[211] European Commission, 'The European Code of Conduct for Efficiency in Data Centres' <https://joint-research-centre.ec.europa.eu/document/download/0549a8bc-02da-4b05-896d-4728a4a54ab4_en> accessed 23 August 2024.
[212] Directive (EU) 2019/424.
[213] *See for example*, Annex II, 1.1.
[214] *See for example*, Annex II, 1.2.

in mind. Additionally, the EU Green Public Procurement criteria for data centres,[215] server rooms, and cloud services provide guidelines for public sector entities to procure environmentally friendly IT infrastructure, driving demand for greener technologies.

In 2023, the European Commission introduced a delegated regulation under the Energy Efficiency Directive to establish an EU-wide scheme for rating the sustainability of data centres.[216] This initiative, which will require data centre operators to report key performance indicators to the EU database by September 2024, aims to increase transparency and promote designs that not only reduce energy and water consumption but also enhance the use of renewable energy and the reuse of waste heat. This regulation marks a significant step toward more robust infrastructure regulation within the EU, yet it still largely focuses on energy efficiency rather than a comprehensive environmental impact assessment.

At the national level, several countries have introduced measures to regulate the environmental impact of data centre infrastructure. In the U.S, the Energy Independence and Security Act of 2007 mandates the Department of Energy and Environmental Protection Agency to establish a *voluntary* national information program to promote energy efficiency in data centres.[217] In addition, the state of Virginia has introduced more stringent regulations, such as prohibiting diesel fuel use in data centres and providing tax incentives for facilities that meet energy efficiency standards.[218]

China, recognising the environmental impact of its rapidly growing data centre industry, introduced mandatory guidelines for green data centres through its Three-Year Action Plan for the Development of New Data Centers.[219]

[215] Criteria for Data Centres, Server Rooms and Cloud Services <Contact support (europa.eu)> accessed 24 August 2024.
[216] Directive 2012/27/EU as amended by Directive 2018/2002/EU.
[217] 121 STAT. 1492 <121 STAT. 1492> accessed 25 August 2024.
[218] Joe Burns, ‘Virginia proposes data centre energy efficiency requirements’ (*facilitiesdive*, 5 January 2024) <Virginia proposes data centre energy efficiency requirements | Facilities Dive> accessed 25 August 2024.
[219] Guozhu Li, Zixuan Sun, Qingqin Wang, Shuai Wang, Kailiang Huang, Naini Zhao, Yanqiang Di, Xudong Zhao, Zishang Zhu, ‘China’s green data center development: Policies and carbon reduction technology path’ (2023) 231 Environmental Research 3, 116248 <China's green data center development:Policies and carbon reduction technology path - ScienceDirect> accessed 15 August 2024.

Overall, regulatory attention has and is being given at supranational and national level to make compute infrastructure such as cloud computing and data centres more sustainable. However, existing supranational regulation should more comprehensively assess environmental impacts beyond energy consumption and guidelines for compliance should consider mandatory enforcement.

III. Part Two: Regulating AI Systems

III.I Why do we still need to regulate AI Systems?

While imposing stricter regulations on foundational components of AI will feed into the broader sustainability of AI, improvements can be made to the EU AI Act to address environmental sustainability of AI as a whole. While AI consists of multiple components, these operate interconnectedly[220] and, therefore, regulation of the system as a whole ensures the integration of these components is as sustainable as possible. For example, while individual components may be energy-efficient, their combined operation in an AI system might result in higher energy use due to poor integration or system management.[221] Component-level regulations, when done appropriately, drive innovation by pushing manufacturers to develop environmentally friendly technologies, whereas system-level regulations encourage integrators (such as providers and deployers) to develop systems that maximise the benefits of these innovations.

Therefore, the goal in amending the EU AI Act would be to create sufficient provision to ensure that various components are integrated and deployed in a sustainable way. Of course, this does not suggest that such provision should be made only in the EU AI Act - rather, the Act should be complemented by other Union law.

Consideration may be given to a separate, stand-alone framework which specifically seeks to address environmental sustainability of AI, however, such a stand-alone framework may be best

[220] Global Partnership on AI Report, 'Climate Change and AI' (GPAI November, 2021) 29 <https://www.gpai.ai/projects/climate-change-and-ai.pdf> accessed 10 July 2024.
[221] Ashkan Enteyari, Alireya Aslani, Rahim Zahedi, Younes Noorollahi, 'Artificial intelligence and machine learning in energy systems: A bibliographic perspective' (2023) 45 Energy Strategy Reviews, 101017.

suited once more about the extent of the environmental impact through reporting has become known. Due to the urgency of the environmental degradation, amendments and additions to the EU AI Act, as an existing framework, may offer a feasible solution to help mitigate AI's environmental impact.

III.II Amendments to the EU AI Act: Enhancing Environmental Protection

In spite of the above, the EU AI Act prior to having been passed, went through various versions, one of which also included stronger provisions on environmental protection. In June 2023, the European Parliament ('**EP**') adopted a series of amendments that markedly enhanced the environmental focus of the European Commission's draft AI Act.[222] These amendments, while not all fully adopted in the final version, may offer valuable insights into the EU AI Act and may better mitigate system-level environmental impacts of AI. The European Parliament's suggestions extended the scope of the Act to include both direct and indirect environmental effects, and they demonstrated a deeper consideration of these impacts throughout the AI lifecycle, although they are not entirely comprehensive. The EP's proposals will be considered concurrent to suggestions for amendments of the EU AI Act.[223]

The following amendments to the Act are suggested:

Explicit Recognition of Environmental Harm

The first step would be including explicit reference to environmental harm in the provisions concerning negative effects which would ensure comprehensive inclusion in related sections, such as **Recital 74**, which currently focuses on accuracy, robustness, and cybersecurity. Amending **Recital 5** to mention environmental harm alongside public interests and fundamental rights would balance the positive acknowledgement in **Recital 1**, which highlights the potential environmental

[222] Amendments adopted by the European Parliament on 14 June 2023 on the proposal for a regulation of the European Parliament and of the Council on laying down harmonised rules on artificial intelligence (Artificial Intelligence Act) and amending certain Union legislative acts (COM(2021)0206 – C9-0146/2021 – 2021/0106(COD)) <Texts adopted - Artificial Intelligence Act - Wednesday, 14 June 2023 (europa.eu)> accessed 30 June 2024.

[223] *Note that the suggested amendments of additions are indicated in bold while existing language as in the EU AI Act is not.*

benefits of AI. Additionally, **Recital 27** should be revised to emphasise the entire lifecycle of AI, from development and implementation to post-use.

Amendment to Recital 5: …. AI may generate risks and cause harm to public interests and fundamental rights… Such harm might be material or immaterial, including physical, psychological, societal, **environmental** or economic harm….
Amendment to Recital 27: … The application of those principles should be translated, when possible, in the design, use and **disposal** of AI models…
Amendment to Recital 74: … The Commission and relevant organisations and stakeholders are encouraged to take due consideration of the mitigation of risks and the negative impacts of the AI system, **including negative impacts to the environment**….

It may also be considered to define what constitutes environmental harm by providing a non-exhaustive list of such impacts, including their qualitative thresholds.[224] This should be done in accordance with other Union law, such as the EU Directive on the protection of the environment through criminal law ('**PECL**')[225] or the Treaty on the Functioning of the European Union ('**TFEU**').[226] This definition may be added to **Article 3** and should cover all natural resources as noted in **Article 191 TFEU** and **Article 1 PECL.**[227]

That being said, due to aforementioned issues relating to the conceptualisation of environmental harm, this may prove challenging - and potentially only possible once more information relating to AI-specific harm is known.

[224] *See for example Article 9 PECL.*
[225] EU Directive 2024/1203EC. *This Directive defines a number of unlawful behaviour that are harmful to human health or the environmental which are subject to penalties.*
[226] Article 3(3), Article 191.
[227] Article 1: *'Pursuant to Article 3(3) of the Treaty on European Union (TEU) and Article 191 of the Treaty on the Functioning of the European Union (TFEU), the Union is committed to ensuring a high level of protection and improvement of the quality of the environment. The environment, in a wide sense, should be protected, as follows from Article 3(3) TEU and Article 191 TFEU, covering all natural resources, including air, water, soil, ecosystems, including ecosystem services and functions, and wild fauna and flora, including habitats, as well as services provided by natural resources.'*

AI's Broader Environmental Impact

Where resource expenditure is mentioned throughout the Act, the focus is largely placed on energy expenditure as mentioned in Chapter 3. This may be changed through clarifying examples, such as in **Article 40(2).** This would increase certainty and recognition of environmental impacts which extend beyond energy consumption.

> **Amendment to Article 40(2):** …The standardisation request shall also ask for deliverables on reporting and documentation processes to improve AI systems' resource performance, such as reducing the high-risk AI system's consumption of energy, **water, minerals, land** and other resources during its lifecycle, and on the **resource**-efficient development of general-purpose AI models…

Strengthened Provisions for HRAIS

It may be considered to include additional and separate provisions specifically imposing requirements against negative environmental impacts for HRAIS - this, of course, would provide the most comprehensive and considered approach in terms of mitigation of environmental impact. While amendments to provisions relating to HRAIS may be useful, another option is to explicitly add provisions relating to sustainability of HRAIS. This may allow for more leeway to comprehensively address environmental concerns. The above suggestions are limited by the fact that they only apply to HRAIS and therefore omit other AI systems which do not necessarily align with the aim of increased accountability and consistency.

Alternatively, as the above might be difficult to achieve in practice, another option would be to amend existing provisions to include environmental protection requirements. **Annex IV** to **Article 11** relating to the requirement of technical documentation for HRAIS can be amended to include metrics related to the environmental consumption of AI systems which would ensure continuous observation of environmental performance throughout the system's lifecycle. Data from environmental impact assessments relating to the regulation of underlying compute can be used to inform this approach.

Amendment to Annex IV (2)(g): … the validation and testing procedures used, including… metrics used to measure accuracy, robustness, **environmental impact**…

Article 12 requires HRAIS to allow for the automatic recording of events over the lifecycle of the system. Expanding this article to include sustainability related information would ensure that AI systems are designed to log environmental data and post-market monitoring.

Addition: Art. 12(3)(d) tracking and reporting environmental metrics, including but not limited to energy consumption, carbon emissions and resource usage during the system's operation.

In regards to transparency obligations, addition to **Article 13(3)** could require environmental performance metrics to be contained in the instructions for use for deployers to increase transparency and overall system efficiency.

Addition: art. 13(3) (viii) the environmental performance metrics of the high-risk AI system, including its energy consumption, carbon emissions, and resource usage during operations, as well as any environmental impacts identified during its development and deployment.

In terms of distributor obligations, **Article 24** stipulates that they must ensure that transport and storage conditions do not jeopardise compliance of obligations under the Act. If environmental protection was more explicitly referred to in the requirements under section 2, then this would have the effect that distributors must also consider the environmental impact of transport and storage, which are also causes of environmental impact.

Reporting of Serious Incidents

As per the analysis in Chapter 3 relating to **Article 73**, amendments may be made to more adequately capture the different dimensions of environmental impact and how the causal link may not be easily identified. Therefore, in the context for environmental harm *only*, flexibility in the timeline for reporting an incident should be provided. Providers should be allowed more time to establish causal links in cases of cumulative or delayed environmental harm.

There also needs to be provision for such impacts that are not feasibly attributable to one provider in order to harmonise with other Union law, such as **Article 191 TFEU**[228] or **Article 2 PEC**L.[229]

Addition to Article 73(2): … In cases of environmental harm, where the harm is cumulative, delayed or diffuse, the timeline may be extended to [insert suitable time frame], provided that the provider can demonstrate ongoing efforts to identify the causal link.
Amendment to Article 73(7): … The Commission shall develop dedicated guidance to facilitate compliance with the obligations set out in paragraph 1 of this Article, **including specific guidelines for identifying, reporting, and investigating cumulative, delayed or diffuse environmental harm.** That guidance shall be issued by 2 August 2025, and shall be assessed regularly.

Enhancing the Risk Management System

The Risk Management System outlined in **Article 9,** specifically for HRAIS, should include the identification and management of environmental risks. This iterative process, planned throughout the AI system's life cycle, would ensure that environmental risks are consistently addressed as it includes the identification of 'known and reasonably foreseeable' risks that the HRAIS can pose.[230] Explicit reference to the environment would not necessarily be needed if it is clarified that environmental protection falls within the Act's definition of fundamental rights. Similar amendment was reflected in the EP's proposals under **Amendment 263.**

Amendment to Article 9 (2)(a): The identification and analysis of the known and the reasonably foreseeable risks that the high-risk AI system can pose to health, **environment,** safety or fundamental rights when the high-risk AI system is used in accordance with its intended purpose…	**EP Proposed Amendment:** (a) identification, estimation and evaluation of the known and the reasonably foreseeable risks that the high-risk AI system can pose to the health or safety of natural persons, their fundamental rights including [...] the environment…

[228] Article 191(2): *'Union policy on the environment shall aim at a high level of protection taking into account the diversity of situations in the various regions of the Union. It shall be based on the precautionary principle and on the principles that preventive action should be taken, that environmental damage should as a priority be rectified at source and that the polluter should pay.'*

[229] Article 2: *'That policy is to be based on the precautionary principle and on the principles that preventive action is to be taken, that environmental damage should as a priority be rectified at source and that the polluter should pay.'*

[230] Article 9(a).

Data Quality

As mentioned in the section relating to the regulation of resources and using FLOPS as a metric, complementary measures such as ensuring that data quality is increased are important to ensure sustainability measures are as effective as possible. The EU AI Act addresses data governance in **Article 10 -** again in the context of HRAIS only. This Article stipulates data quality, however, could further reference data quality in the context of best possible system efficiency. Additionally, data quality should be a consideration in the context of GPAIM systems and not just HRAIS.

> **Addition to Article 10(4)**: **… Additionally, data sets shall be evaluated where necessary to ensure that these contextual elements are accurately represented in a way that enhances system efficiency and reduces the likelihood of inefficiencies during deployment…**

Strengthened Provisions for GPAIM

In regards to GPAIM, at the very minimum, models that fall within this scope, should have increased responsibilities in terms of environmental protection. As has been analysed, provisions relating to these models are mainly *voluntary* and insufficient in addressing environmental impact. Research has suggested that voluntary pressures are insufficient in effecting positive environmental outcomes.[231]

Binding provisions are needed, otherwise environmental protection will not be prioritised over short-term profits.[232] Unless systems are classed as HRAIS based on their impact to the environment (i.e. environmental protection is an increased consideration in the classification as HRAIS), binding provisions are needed for GPAIM.

Further, requirements should be imposed to ensure GPAIM comply by codes of conduct. **Article 95** would therefore need to be amended to reflect a shift from voluntary to mandatory.

> **Amendment to Article 95(1):** The AI Office and the Member States shall **require** and

[231] J. Alberto Aragòn-Correa, Alfred A. Marcus and David Vogel, 'The Effects of Mandatory and Voluntary Regulatory Pressures on Firms' Environmental Strategies: A Review and Recommendations for Future Research' (2020) 14 Academy of Management Annals 1.
[232] ibid.

facilitate the drawing up of codes of conduct… intended to **ensure** the application to AI systems, other than high-risk AI systems…

The commercial implications of this amendment may be mitigated through consideration of **Article 95(4)** wherein interests and needs of SMEs, including startups, are to be taken into account when drawing up codes of conduct.

Accordingly, **Recital 165** again does nothing in pressuring providers which are not deemed high risk in actually creating codes of conduct. Changing the wording could substantially increase the pressure for such providers to comply.

Amendment to Recital 165: … Providers of AI systems that are not high-risk should be required to create codes of conduct [...] Providers and, as appropriate, deployers of all AI systems, high-risk or not, and AI models **should apply** additional requirements related, for example, to the elements of the Union's Ethics Guidelines for Trustworthy AI, environmental sustainability…

As mentioned, implementation of Codes of Practice has largely been ineffective.[233] If they are to remain voluntary then a monitoring framework should accompany this provision, so it can be assessed as to how participants are implements their commitments and whether the codes of practice need to be continuously strengthened.

Amendment to Recital 165: … To ensure that the voluntary codes of conduct are effective, they should be based on clear objectives and key performance indicators to measure the achievement of those objectives… [**insert details on a monitoring framework].**

Further, **Annex XI** under **Article 53**, record-keeping for providers of GPAIM should include information relating to resource expenditure beyond energy consumption, such as water consumption. Here, water consumption is added as it is a quantifiable metric.

[233] ERGA, 'ERGA Report on Disinformation: Assessment of the Implementation of the Code of Practice' (ERGA) 43 <ERGA-2019-report-published-2020-LQ.pdf (erga-online.eu)> accessed 23 august 2024.

Amendment to XI (2)(e): … (e) known or estimated energy **and water** consumption of the model. With regard to point (e), where the energy **and water** consumption of the model is unknown, the energy **and water** consumption may be based on information about computational resources used…

Categorising Environmentally Detrimental AI Systems as HRAIS

One significant amendment could be to categorise AI systems with particularly detrimental environmental impacts as HRAIS. This categorisation would require an amendment to **Annex III** and incentivise innovators to develop more efficient systems to avoid stringent requirements, so they may not fall within this category. However, defining what constitutes sufficient environmental risk requires clear metrics. If hardware regulation is strengthened as proposed above, increased transparency would facilitate the quantification process of environmental impacts. This approach might challenge the EU's principle of technology neutrality, and it is difficult to determine based on current data which systems might fall within this scope.

Clarification of Environmental Protection as a Fundamental Right

Clarifying whether environmental protection is considered a fundamental right under the Act can also be an option. This clarification would affect **Article 79**, where risk is defined as risks to health or safety or fundamental rights. Clearly defining environmental protection as a fundamental right would enhance the Act's scope and ensure environmental risks are adequately addressed.

In doing so, Fundamental Rights Impact Assessments ('**FRIA**') set forth in **Article 27** could serve as a tool for continuous risk assessment.[234] This assessment should explicitly refer to environmental harm, ensuring ongoing monitoring of risks beyond initial deployment as the wording in the current version only refers to 'specific risks of harm likely to impact categories of natural persons.'

[234] *Although it must be noted that the scope of this Article is narrow. In its current form it is limited to certain HRAIS intended for use in areas listed in point 2 of Annex III. As currently worded, it is also only a one-time assessment - applying only to the first use of the HRAIS.*

The following are suggestions for additions to the EU AI Act:

Addressing the Disparate Impacts across Member States

Explicit provisions could be added to address how environmental impacts may be felt differently across Member States or third countries. This inclusion would ensure proportionality and constitute a more equitable approach to environmental protection given that the environmental impacts of AI are geographically varied.

Research on the Environmental Impact of AI

Further research and studies should be mandated within the Act in an attempt to better understand AI-specific environmental impacts. Regulatory inspiration may be taken by the Artificial Intelligence Environmental Impacts Act of 2024 ('**EIA 2024**') was introduced by the United States Congress.[235]

The EIA 2024 requires the Environmental Protection Agency to study the environmental impacts of AI and for the National Institute of Standard and Technology to then assess these impacts, ultimately to create a voluntary reporting system for AI developers to report environmental effects.[236] While this reporting system is still meant to be voluntary, provisions for specific research to be conducted, would positively contribute to the lack of data existing and may ultimately better inform policies at Union level. EIAs from hardware may be able to feed into overall assessment of environmental impact across systems and models.

[235] *It must be noted that the EIA 2024 is still a Bill and has not been passed yet:* S.3732 11th Congress 2nd Session <https://www.congress.gov/bill/118th-congress/senate-bill/3732/text> accessed 9 August 2024.

[236] Ed Markey United States Senator for Massachusetts, 'Markey, Heinrich, Eshoo, Beyer introduce legislation to investigate, measure environmental impacts of artificial intelligence' (1 February 2024) <https://www.markey.senate.gov/news/press-releases/markey-heinrich-eshoo-beyer-introduce-legislation-to-investigate-measure-environmental-impacts-of-artificial-intelligence> accessed 9 August 2024.

CHAPTER 5

I. Conclusion

The rapid growth and integration of AI technologies across various sectors has transformed industries, driving significant advancements. However, as this thesis has demonstrated, the environmental impact of AI is a complex and multifaceted issue that extends across AI's entire lifecycle - from production to operation and disposal. This environmental impact, while interrelated to broader ICT environmental impact, has distinctive features due to AI's large computational requirements, particularly for energy-intensive tasks like training LLMs. Addressing these impacts through effective regulation is crucial to promote reconciliation between the global climate targets and AI development.

The central research questions of this thesis have sought to examine these complexities:

***Q1.* What are the known environmental impacts of computer-related technologies and applications, and how do they vary from other AI technologies and applications?**

AI technologies have diverse and significant environmental impacts. Direct impacts include the energy consumption and GHG emissions associated with AI's production and operational stages, particularly during data processing, model training, and inference. Water usage and e-waste from hardware disposal further contribute to AI's environmental toll. Indirect impacts, such as rebound effects through, *i.a,* increased consumption patterns, and socio-economic consequences, can exacerbate AI's environmental footprint. These impacts differ from those of other compute-related technologies, although interrelated, due to AI's intensive computational demands, which are not always present in the more traditional digital applications.

***Q2.* How effective is the EU AI Act in addressing these environmental impacts?**

The EU AI Act represents a significant legislative effort to regulate AI at a transnational level, seeking to balance innovation, consumer protection, and fundamental rights. While the Act recognises AI's potential for environmental benefits, such as optimising energy use and contributing to sustainability goals, it falls short of comprehensively addressing AI's negative environmental impacts. The Act's focus on promoting AI for sustainability does not extend to ensuring sustainability of AI itself. The gap is evident in the lack of explicit provisions for managing the lifecycle environmental impacts of AI, including energy consumption, water usage, and e-waste.

Moreover, while the Act includes voluntary measures, such as codes of conduct for promoting environmental sustainability, their non-binding nature raises concerns about their effectiveness. Research suggests that voluntary compliance with such initiatives is often low, highlighting the need for stronger, legally binding environmental protections. Additionally, the Act's risk-based approach to AI regulation does not adequately consider environmental risks, particularly for systems like GPAIM, which can have substantial environmental impacts yet evade stricter regulatory scrutiny.

***Q3.* What should the objectives and scope of regulations of AI's environmental impacts be, and how should they differ from existing regulations?**

To increase the sustainability of AI and related technologies, this thesis has proposed a two-pronged approach: stricter regulatory measures at component-level and system-level. As demonstrated throughout this thesis, AI compute is a crucial strategy for mitigating the environmental impact of AI systems. Regulating compute offers a tangible and measurable approach. Compute is also easier to detect, quantify, and regulate due to its physical presence and highly concentrated supply chain.

PART ONE: At component-level, regulation can be regulated at three levels, through regulating hardware, resources and infrastructure. Targeting AI-specific hardware like GPUs and FGAs provides a way to address the environmental impact of high-compute AI models. These components are integral to AI operations and have distinct environmental footprints, including energy consumption, mineral use, and water-intensive manufacturing processes. Regulating these aspects allows for a focused approach that avoids stifling broader technological innovation.

However, care must be taken to avoid bottlenecks in the AI value chain that could lead to economic disadvantages.

Regulating resources may be done through using FLOPS as a quantifiable metric, and it has already been incorporated into both U.S. and EU regulations. However, this metric is limited as it only captures the computational power used, without accounting for other factors, such as data quality which may lead to inefficiencies. Regulation must set appropriate thresholds that are reviewed to ensure only the most resource-intensive models are subject to stringent oversight, balancing environmental protection with innovation.

Infrastructure, such as data centres and cloud computing facilities, are a significant source of energy consumption and carbon emissions. Existing regulatory frameworks, such as the **EU** DC CoC and the EU's Ecodesign for Sustainable Products Regulation, have laid the groundwork for promoting energy-efficient infrastructure. However, more comprehensive regulations are needed that go beyond energy efficiency and address broader environmental impacts, such as water consumption and resource use.

Overly stringent regulations could deter investment in AI research and development or push manufacturers to relocate to less regulated regions. Therefore, a combination of CAC regulations and MBIs should be employed. CAC regulations can set baseline environmental standards, while MBIs can incentivise the development of more sustainable hardware and infrastructure.

To foster innovation, regulatory sandboxes should be promoted. These controlled environments allow companies to experiment with new technologies without being burdened by full regulatory compliance, facilitating the development of sustainable solutions for AI hardware. Additionally, mandatory EIAs tailored to specific environmental risks should be introduced to ensure sustainability across the lifecycle of AI components. Measures must be taken to support firms in implementing these EIAs, considering past challenges such entities have experienced because of increased reporting requirements. EIAs would provide transparency and valuable data across the supply chain, informing AI developers and regulators about the environmental footprint at component level.

PART TWO: Greater sustainability at component-level may feed into overall sustainability of AI systems only if such integration is done efficiently. Therefore, regulation at system-level is needed to ensure the integration and operation of these components do not negate the environmental benefits achieved at component level. This thesis has argued that the EU AI Act represents a suitable framework for addressing environmental risks at system level, primarily as the Act's underlying purpose already considers environmental protection, the Act considers other interests and is centred around risk as well as being sector-agnostic.

Although previous iterations of the Act have included stronger environmental provisions, further amendments and additions are needed to ensure comprehensive coverage. The goal should be to embed environmental considerations throughout the lifecycle of AI systems. This could involve explicitly recognising environmental harm in the Act, broadening the scope of resource efficiency measures, and imposing binding environmental protection requirements on HRAIS and GPAIS.

Moreover, categorising AI systems with significant environmental impacts as HRAIS could incentivise the development of more efficient technologies, reducing their environmental footprint. Strengthening transparency, risk management, and record-keeping requirements, alongside enhancing data governance and environmental metrics, would further contribute to this goal.

As the understanding of AI's environmental impact evolves, additional research and data collection will be critical. Ongoing studies and reporting mechanisms can better inform policymakers and enable continuous improvements in regulations, ensuring that AI development aligns with the EU's broader goals of sustainability and environmental protection. As data becomes increasingly available, consideration may be given to a standalone framework that targets AI's and technology's environmental impacts in a more targeted and comprehensive manner - the key being accurate and valuable data and information on these impacts.

***Q4.* How can the regulation of negative environmental impacts of AI ensure a balance between individual freedoms, innovation and competition that, amongst others, may offer positive (environmental) benefits?**

Addressing the environmental impacts of AI requires a multifaceted approach that carefully balances innovation with sustainability. The rapid pace of AI development presents a significant challenge for regulators, as existing frameworks often lag behind technological advancements.

This ‘pacing problem’ means that regulations must be both flexible and adaptive, capable of evolving alongside the technology they govern. Rigid, blanket regulations that fail to accommodate the speed of AI innovation are likely to be counterproductive, stifling progress without effectively addressing the environmental concerns.

To overcome these challenges, collaboration between regulators and industry stakeholders is crucial. Bridging the information gap between these groups can lead to more informed and effective regulations that reflect both technological realities and environmental priorities. Engaging with industry experts ensures that regulations are grounded in current data and technological capabilities, while also allowing for the secure sharing of sensitive information. This collaborative approach can help mitigate the risks posed by information asymmetries and create more robust regulatory frameworks.

Further, AI’s global nature demands harmonised regulations across borders to prevent discrepancies that could hinder international cooperation and competition. A transnational approach is necessary to address the environmental impacts of AI, which are not confined to national boundaries. Such an approach can facilitate innovation while ensuring environmental standards are upheld globally.

The environmental impacts of AI are diverse and complex, extending across the entire lifecycle of AI systems, from the extraction of raw materials to the deployment of AI in various industries. Therefore, a comprehensive regulatory strategy must address both component-level (e.g. hardware, data centres) and system-level (e.g. AI applications and integrations). This requires a combination of regulatory tools, including MBIs and CAC regulations. MBIs can incentivise innovation and efficiency, while CAC regulations ensure that minimum environmental standards are met across the board.

I. Technical Definitions

AI consists of numerous subsets. As Christen et al noted, 'AI must be separated from the technologies which implement it.'[237] As each of these implementing technologies have varying environmental impact, it is important to understand the different technical forms that AI can take.

I.I Machine Learning

ML is a cornerstone of current AI systems and relies on data-driven models that leverage past information contained within training datasets to detect patterns and improve its own predictive capabilities.[238] There are three types of ML: supervised, unsupervised and reinforcement learning.[239] In unsupervised learning, models are trained on datasets without explicit instructions or labelled data. Instead, they identify patterns and structures by measuring the densities or similarities of data points within the dataset. ML does not need to search for patterns themselves; rather, when provided with unlabelled data, ML autonomously recognises the patterns.

Supervised learning, on the other hand, involves training models on datasets containing labelled data. Programs are provided with labelled data, and the underlying algorithms are developed on inputs. Subsequently, the system is tested to ascertain its ability to accurately apply labels to new data. Learning in this form occurs when examples are used to train an algorithm to map input variables onto desired outputs. Using this approach, machine learning models can identify patterns linking inputs to outputs and reproduce these patterns by employing the rules acquired during training to classify new inputs.

[237] Markus Christen, Clemens Mader, Johann Cas, et Al., 'Wenn Algorithmen für uns entscheiden: Chancen und Risiken der künstlichen Intelligenz', in TA-SWISS Publikationsreihe (Hrsg.): TA 72/2020. Zürich: vdf, 2020. <https://vdf.ch/wenn-algorithmen-fur-uns-entscheiden-chancen-und-risiken-der-kunstlichen- intelligenz-e-book.html> accessed 20 May 2024.

[238] Information Commissioner's Office, 'Definitions of AI', (ICO) <https://ico.org.uk/for-organisations/uk-gdpr-guidance-and-resources/artificial-intelligence/explaining-decisions-made-with-artificial-intelligence/part-1-the-basics-of-explaining-ai/definitions/> accessed 20 May 2024.

[239] Park Thaichon, Sara Quach, *Artificial Intelligence for Marketing Management*, (Routledge, 2022).

Reinforcement learning is based on a feedback reward system in which an AI is trained on command inputs and upon each action feedback is received which is used by the AI system to improve its own performance.[240]

I.II Deep Learning

Deep learning (‘**DL**’) is a branch of ML and AI that operates on the basis of deep neural networks (‘**DNNs**’) which are composed of multiple interconnected layers of neurons - inspired by the electro-chemical neural networks found in the (human) brain.[241] Each of the layers receives input data, and the neurons propagate the input signal into subsequent layers. The hidden layers perform complex mathematical operations on the inputs, ultimately delivering processed data to the output layer, which returns the output to the user. The DNNs mimic the intricate decisionmaking capabilities of the brain and are trained on extensive datasets to identify, classify and recognise patterns, as well as make predictions and decisions. Additional layers contribute to increased accuracy, and differences between the output and the labelled data are termed the ‘error’.[242]

The DNNs are able to ‘backpropagate’ in which it adjusts its parameters based on the error of its predictions, learning from inaccuracies it makes. Crucially, in order to do the above, deep learning systems require substantial amounts of data for training and rely on powerful hardware, such as GPUs, to process the complex computations involved. LLMs are built on machine learning and can respond to natural human language and use data analysis to answer an unstructured question. LLMs employ particular neural networks called transformer models which are able to gauge context which is crucial in understanding and generating human language.[243]

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[240] Free Learning Platform for Better Future, ‘Subsets of AI’ <https://www.javatpoint.com/subsets-of-ai> accessed 20 May 2024.
[241] Philip Boucher, ‘Artificial intelligence: How does it work, why does it matter, and what can we do about it?’ (European Parliament, June 2020) <https://www.europarl.europa.eu/RegData/etudes/STUD/2020/641547/EPRS_STU%282020%29641547_EN.pdf> accessed 23 July 2024.
[242] ibid.
[243] Cloudflare, ‘What is a large language model (LLM)’ (Cloudflare) <https://www.cloudflare.com/en-gb/learning/ai/what-is-large-language-model/> accessed 20 May 2024.

II. Regulatory Challenges and Resulting Priorities

Regulating emerging and disruptive technologies presents several significant challenges - it can either catalyse technological innovation or pose significant obstacles to its advancement. When these challenges relating to the regulation of technology in general intersect with the specific environmental issues that require to be addressed (as identified in Chapter 2), they create a complex and even more demanding regulatory landscape.

The 'pacing problem' highlights that existing regulatory frameworks often struggle to keep pace with the rapid evolution of technology, leading to outdated or ineffective regulations.[244] This 'cat and mouse' race has been one of the greatest challenges in regulating technology for decades.[245]

Priority 1: Regulatory frameworks need to be flexible and able to adapt to the rapid pace of technological advancement.

The inherent information asymmetries between regulatory and industry stakeholders can exacerbate this issue.[246] Regulators may lack the expertise and up-to-date knowledge or data that industry experts possess, leading to poorly designed regulations that do not effectively address industry realities.[247] The information sought by regulators might also be considered confidential and increase risk surrounding cybersecurity.[248] This can be seen in the Dallas lawsuit over the water consumption of Google's data centre - in which Google argues that the water use was a 'trade secret'.[249]

[244] Gary E. Marchant, Bradan R. Allenby, Joseph R. Herkert, The Growing Gap Between Emerging Technologies and Legal-Ethical Oversight (Springer Dordrecht, 2011) 199.
[245] ibid.
[246] Christopher Ruof, Regulating Financial Innovation (Palgrave Macmillan Cham, 2023) 187.
[247] Xiaohan Zhand, 'Information Asymmetry and Uncertainty in Artificial Intelligence' (Medium, 8 September 2017) <Information Asymmetry and Uncertainty in Artificial Intelligence | by Xiaohan Zhang | Medium> accessed 21 August 2024.
[248] Konstantin Pilz, Lennart Heim, 'Compute at Scale: A Broad Investigation into the Data Center Industry' (Cornell University, 5 November 2023) <[2311.02651] Compute at Scale: A Broad Investigation into the Data Center Industry (arxiv.org)> accessed 28 July 2024.
[249] Mike Rogoway, 'Google's water use is soaring in The Dallas, records show, with two more data centres to come' (Oregon Live, 22 February 2023) <The Dalles settles public records lawsuit over Google's data centres, will disclose water use to The Oregonian/OregonLive - oregonlive.com> accessed 29 July 2024.

Priority 2: Regulatory frameworks need to foster stronger collaboration between regulatory, industry experts, and other stakeholders to bridge information asymmetries. Regulators need access to updated data and expertise while ensuring the secure sharing of sensitive information.

Thirdly, cross-border regulatory discrepancies can hinder international collaboration and innovation and competition, as differing regulations create barriers for companies operating on a global scale (as most of the ICT industry does).[250] The global nature of both technology and environmental impact necessitates a transnational regulatory instrument.

In addition, the decentralised, 'permissionless' nature of much of the digital economy allows for rapid innovation without prior regulatory approval.[251] An environment fostering innovation and competition is also required due to the concentrated supply chain of AI. This complicates efforts to enforce environmental obligations. Therefore, there is a need for harmonised regulations that balance competing interests - encouraging technological progress, promoting a competitive and innovative environment.

Priority 3: Regulatory frameworks must work towards the harmonisation of regulations at multinational level to facilitate global cooperation, competition and innovation.[252]

Fourthly, the AI supply chain - producers, providers and deployers - is extensive and accountability needs to vary according to associated responsibilities. Different actors along the supply chain also need to cooperate with one another if regulation is to target the system as a whole.

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250 Markus Anderljung, Joslyn Barnhart, Anton Korinek, Jade Leung, Cullen O'Keefe, Jess Whittlestone, Shahar Avin, Miles Brundage, Justin Bullock, Duncan Cass-Beggs, Ben Chang, Tantum Collins, Tim Fist, Gillian Hadfield, Alan Hayes, Lewis Ho, Sara Hooker, Eric Horvitz, Noam Kolt, Jonas Schuett, Yonadav Shavit, Divya Siddarth, Robert Trager, Kevin Wolf, 'Frontier AI Regulation: Managing Emerging Risks to Public Safety' (Cornell University, 6 July 2023) <[2307.03718] Frontier AI Regulation: Managing Emerging Risks to Public Safety (arxiv.org)> accessed 20 July 2024.
251 ibid.
252 *This is also reflected in the OECD recommendations to governments - highlighting the need for cooperation across borders and sectors.*

Priority 4: Regulatory frameworks must define the responsibilities of each actor, ensuring that all parties cooperate to address the environmental impact of every stage of the AI lifecycle.

Referring back to the environmental impacts identified in Chapter 2, it is clear that the impacts are diverse ranging from direct impacts such as GHG emissions, electricity consumption and water consumption to indirect impacts extending to broader consumptive behaviour, deployment in controversial industries and social implications. Therefore, a systematic approach is needed to address these impacts rather than focussing on one impact, as has been previously done with GHG emissions.

Priority 5: Regulatory frameworks must systematically and holistically address all relevant environmental impacts. This includes addressing impacts that occur throughout AI's entire lifecycle (e.g. GHG emissions, water consumption etc).

Addressing these challenges associated with emerging technologies, particularly AI, requires a dynamic and collaborative approach. As this thesis continues to explore market-based instruments ('**MBIs**') and prescriptive regulatory approaches, often termed command-and-control ('**CAC**') regulations, it is crucial to contextualise these broader challenges within specific regulatory strategies.

II.I Regulatory Tools: Market-based Incentives vs Prescriptive Regulatory Approaches

As regulatory challenges relating to AI and its environmental impact have been explored, and resulting regulatory goals identified, the discussion turns to examining regulatory tools. The debate between MBIs and CAC regulations is central to determining the most effective strategy for managing AI's environmental footprint.

II.I.I The Role of MBIs and Limitations

MBIs, such as carbon taxes, cap-and-trade programs, and baseline-and-credit systems, are increasingly seen as effective tools for regulating environmental impacts in complex and global industries like AI.[253] They work through creating financial incentives for companies to reduce pollution, aligning their economic interests with environmental goals.[254]

For example, a carbon tax on the energy consumption of data centres may incentivise AI companies to reduce their carbon footprint by adopting energy efficient technologies.[255] Although it must be said that it might have the reverse effect intended, encouraging companies to relocate to locations that don't impose such costs, or companies passing on the costs to consumers.[256] Similarly, a cap-and-trade system would allow companies to buy and sell emission allowances, promoting cost-effective emissions reductions across the industry.[257] MBIs also provide dynamic incentives for technology innovation, encouraging firms to continuously seek more efficient and sustainable practices.[258]

That being said, MBIs cannot serve as a standalone solution; they must be complemented by prescriptive regulation. When used in isolation, MBIs may worsen the issue of tech companies failing to disclose their true carbon footprints, as purchasing credits can obscure the actual environmental costs, which are not accurately reflected in their carbon accounts.[259]

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[253] *As this work is not an economic paper, an in-depth analysis of these different tools is outwith the scope of this thesis. Reference can be made to: Robert N. Stavins, 'Chapter 9 - Experience with Market-Based Environmental Policy Instruments' (2003) Handbook of Environmental Economics 1 355; Maryam Mazaheri, Jaime Bonnin Roca, Arjan Markus, Bob Walrave, 'Market-based instruments and sustainable innovation: A systematic literature review and critique' (2022) 373 Journal of Cleaner Production 133947.*

[254] ibid.

[255] Shafik Hebous, Nate Vernon-Lin, 'Carbon Emissions from AI and Crypto are Surging and Tax Policy Can Help' (IMF Blog, 15 August 2024) <Carbon Emissions from AI and Crypto Are Surging and Tax Policy Can Help (imf.org)> accessed 21 August 2024.

[256] Jariel Arvin, 'One weird trick to fix climate change: Close the offshore wealth loophole' (Vox, 5 March 2021) < Carbon taxes don't reduce emissions but closing offshore tax havens can | Vo> accessed 27 August 2024; Roumeen Islam 'What a carbon tax can do and why it cannot do it all' (World Bank Blogs, 19 January 2022) <What a carbon tax can do and why it cannot do it all (worldbank.org)> accessed 28 August 2024.

[257] IEA, 'Implementing Effective Emissions Trading Systems - defining the role' (IEA) <Defining the role – Implementing Effective Emissions Trading Systems – Analysis - IEA> accessed 10 August 2024.

[258] Puja Singhai, 'Environmental Regulations: Lessons from the Command-and-Control Approach' (2018) Deutsches Institut für Wirtschaftsforschung 1.

[259] ibid (n64).

II.I.II The Role of CAC Approaches and Limitations

CAC regulations have been the traditional method of environmental regulation, often involving technology-based or performance-based standards that set uniform requirements for pollution control.[260] CAC regulation is consistent with Porter's theory which notes that stringent regulation can actually serve to promote technology innovation, as firms seek to continuously innovate to comply with these.[261] However, these approaches have significant limitations, particularly in a rapidly evolving industry like AI.

CAC regulations tend to impose similar pollution-control burdens on all firms, regardless of their individual circumstances, which can lead to inefficiencies.[262] They also provide little incentive for innovation, as companies are only required to meet the minimum standards set by the regulations.[263] Therefore, in some cases, CAC approaches even stifle the development of new technologies that could lead to greater environmental benefit.

Moreover, achieving cost-effectiveness with CAC approaches would require setting different standards for each pollution source, necessitating detailed information about the compliance costs each firm faces, which is an impractical and resource-intensive task.

II.I.III Hybrid Approach

Given the limitations of both MBIs and CAC approaches, a hybrid regulatory strategy might offer the most effective solution for mitigating AI's environmental impact. This strategy would combine the flexibility and innovation incentives of MBIs with the enforceable standards of CAC regulations, ensuring that both global and localised environmental issues are addressed.

For example, MBIs could be used to regulate GHG emissions, where the flexibility to innovate and reduce costs is crucial. Simultaneously, CAC regulations could enforce strict limits on water usage in data centres located in water scarce regions, ensuring that local environmental impacts

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260 ibid.

261 Michael E. Porter, *The Competitive Advantage of Nations* (New York: Free Press, 1990).

262 ibid (n160) 2.

263 Wallace E. Oates, Paul R. Portney, Albert M.McGartland, 'The New Benefits of Incentive-Based Regulation: A Case Study of Environmental Standard Setting' (1989) The American Economic Review 5, 1233.

are managed effectively. Such a hybrid approach would require careful design to ensure that the regulatory framework is both flexible and predictable, addressing the concerns of businesses while still achieving the desired environmental outcomes.

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