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Navigating the AI Paradox: Tackling Energy Poverty and Reducing Environmental Impact through Sustainable Artificial Intelligence Development

di
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1. Introduction

Artificial Intelligence (AI) has emerged as a powerful and transformative technology with the potential to revolutionize the energy industry – and not only[1]. Its applications range from designing energy-efficient buildings and optimizing resource utilization to improving the reliability and security of energy systems[2].

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[1] Y. K. DWIVEDI, L. HUGHES, E. ISMAGILOVA, G. AARTS, C. COOMBS, T. CRICK, Y. DUAN, R. DWIVEDI, J. EDWARDS and A. EIRUG, *Artificial Intelligence (AI): Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy*, in *International Journal of Information Management*, 2021, 57 See also T. AHMAD, D. ZHANG, C. HUANG, H. ZHANG, N. DAI, Y. SONG and H. CHEN, *Artificial intelligence in sustainable energy industry: Status Quo, challenges and opportunities*, in *Journal of Cleaner Production*, 2021, 289

[2] P. H. SHAIKH, N. B. M. NOR, P. NALLAGOWNDEN, I. ELAMVAZUTHI and T. IBRAHIM, *Intelligent multi-objective control and management for smart energy efficient buildings*, in *International Journal of Electrical Power & Energy Systems*, 2016, 74 See also S. KHANMOHAMMADI, F. MUSHARAVATI and R. TARIQ, *A framework of data modeling and artificial intelligence for environmental-friendly energy system: Application of Kalina cycle improved with fuel cell and thermoelectric module*, in *Process Safety and Environmental Protection*, 2022, 164

AI has shown promise in addressing the pressing issue of energy poverty, which affects millions of people worldwide who lack access to reliable, affordable, and modern energy services. Being a multifaceted problem, energy poverty is a complex challenge that has significant social, economic, and environmental implications, it exacerbates inequality, hinders economic development, and contributes to environmental degradation, making it a critical global challenge that requires innovative solutions[3]. Furthermore, it is accepted that the correlation between carbon emission and energy poverty is a complex issue[4], it is not for this paper to discuss.

AI technologies, such as machine learning and deep learning, have demonstrated the ability to optimize energy consumption, enhance system reliability, and support the integration of renewable energy sources, making them valuable tools for addressing energy poverty[5]. Furthermore, AI can be used to power applications such as smart thermostats and appliances in order to allow them to learn the habits of users and optimize energy usage based on these patterns. This can significantly reduce CO2 emissions and energy bills, helping those struggling with energy costs to have better access to energy. AI can also facilitate energy trading exploiting its predictive capabilities, households with solar panels can predict how much excess energy they will have and trade it more effectively, encouraging the transition to renewable energy. Even applications that do not directly relate to energy may prove AI to be an ally in reducing emissions and energy poverty. For instance, Citymapper is an app which uses AI to provide the best public transportation routes to go from A to B, effectively incentivising to use public transport by making it easier. In fact, making public transportation more efficient leads to reduced fuel

[3] M. GONZÁLEZ-EGUINO, *Energy poverty: An overview*, in *Renewable and sustainable energy reviews*, 2015, 47 See also, K. KAYGUSUZ, *Energy services and energy poverty for sustainable rural development*, in ibid.2011, 15 (2);,

[4] N. BONATZ, R. GUO, W. WU and L. LIU, *A comparative study of the interlinkages between energy poverty and low carbon development in China and Germany by developing an energy poverty index*, in *Energy and buildings*, 2019, 183 See also K. DONG, Q. JIANG, M. SHAHBAZ and J. ZHAO, *Does low-carbon energy transition mitigate energy poverty? The case of natural gas for China*, in *Energy Economics*, 2021, 99

[5] B. K. BOSE, *Artificial intelligence techniques in smart grid and renewable energy systems—Some example applications*, in *Proceedings of the IEEE*, 2017, 105 (11);

consumption and costs, thus less emissions[6]. There is no doubt that AI can be a strong ally in the war against energy poverty.

However, the development and deployment of AI technologies are not without environmental costs[7]. The computational power required to train and tune complex AI models, particularly deep learning and natural language processing (NLP) models, can result in significant energy consumption and carbon emissions[8]. Given the dual nature of AI as both a potential solution to energy poverty and a contributor to environmental degradation, it is imperative that policymakers, industry stakeholders, and AI researchers consider the ethical and sustainable allocation of resources when developing and deploying AI technologies[9]. This includes examining the environmental impact of AI development, exploring the economic implications of AI model training and tuning, and investigating policy considerations for promoting AI sustainability[10].

This paper aims to provide a comprehensive analysis of the various dimensions of sustainable AI development, including the environmental impact of AI and policy considerations for AI sustainability. Through a holistic and interdisciplinary approach, the paper will contribute to the ongoing dialogue on sustainable AI development and provide valuable insights for policymakers, industry stakeholders, and AI researchers seeking to harness the transformative potential of AI in an environmentally responsible and equitable manner. In fact, the point is made that by prioritizing sustainability in AI innovation, we can ensure that the development of AI technologies not only addresses pressing global challenges,

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6 Q.-L. JING, H.-Z. LIU, W.-Q. YU and X. HE, *The Impact of Public Transportation on Carbon Emissions—From the Perspective of Energy Consumption*, in *Sustainability*, 2022, 14 (10);

7 P. DHAR, *The carbon impact of artificial intelligence*, in *Nature Machine Intelligence*, 2020, 2 (8);

8 J. DODGE, T. PREWITT, R. TACHET DES COMBES, E. ODMARK, R. SCHWARTZ, E. STRUBELL, A. S. LUCCIONI, N. A. SMITH, N. DECARIO and W. BUCHANAN, *Measuring the carbon intensity of ai in cloud instances*, in *2022 ACM Conference on Fairness, Accountability, and Transparency*, 2022, ibid.

9 M. LABBE and R. SCHMELZER, *AI and climate change: the mixed impact of machine learning*, 2021, avaliable at https://www.techtarget.com/searchenterpriseai/feature/AI-and-climate-change-The-mixed-impact-of-machine-learning;

10 R. VINUESA, H. AZIZPOUR, I. LEITE, M. BALAAM, V. DIGNUM, S. DOMISCH, A. FELLÄNDER, S. D. LANGHANS, M. TEGMARK and F. FUSO NERINI, *The role of artificial intelligence in achieving the Sustainable Development Goals*, in *Nature communications*, 2020, 11 (1);

such as energy poverty but does so in a way that minimizes their environmental impact and promotes a more sustainable and just future for all.

2. The Environmental Impact of AI Development

As AI technologies become more sophisticated and their applications more diverse, the process of training AI models has become increasingly resource-intensive, particularly for deep learning and NLP models[11]. The computational requirements for training these models can lead to significant energy consumption and, consequently, substantial carbon dioxide emissions. Putting this in familiar terms, training a single NLP model on a GPU can produce approximately 600,000 lb of carbon dioxide emissions. This is equivalent to the emissions produced by five cars over their entire lifetime[12]. Additionally, Google's AlphaGo Zero, which gained widespread attention for its remarkable achievements in the game of Go, generated 96 tonnes of CO2 during its 40 days of research training. This amounts to the carbon footprint of 23 American homes or 1,000 hours of air travel[13].

The substantial carbon emissions associated with AI training have a direct impact on the environment, contributing to climate change and exacerbating the global energy crisis[14]. With AI technologies becoming more prevalent and resource-intensive, the environmental impact of AI development is a critical concern that must be addressed. The carbon emissions produced by AI development can be compared to those generated by various other industries to better understand the extent of its environmental impact. For instance, the aviation industry, which is often cited as a significant contributor to greenhouse gas emissions, is responsible

[11] E. STRUBELL, A. GANESH and A. MCCALLUM, *Energy and Policy Considerations for Deep Learning in NLP*, 2019, avaliable at https://arxiv.org/abs/1906.02243;

[12] K. HAO, *Training a single AI model can emit as much carbon as five cars in their lifetimes*, in *MIT technology Review*, 2019, 75 See also R. TOEWS, *Deep learning's carbon emissions problem*, 2020, avaliable at https://www.forbes.com/sites/robtoews/2020/06/17/deep-learnings-climate-change-problem/?sh=1b193ec86b43;

[13] A. VAN WYNSBERGHE, *Sustainable AI: AI for sustainability and the sustainability of AI*, in *AI and Ethics*, 2021, 1 (3);

[14] J. COWLS, A. TSAMADOS, M. TADDEO and L. FLORIDI, *The AI gambit: leveraging artificial intelligence to combat climate change—opportunities, challenges, and recommendations*, in *Ai & Society*, 2021, 38

for roughly 2% of global CO2 emissions[15]. In comparison is the energy consumption of data centres, which are essential for supporting the computational demands of AI development, account for approximately 1% of global electricity consumption[16], and their energy use is projected to increase rapidly in the coming years – projected to reach 3% of global energy consumption by 2025[17] –, driven primarily by the growth of AI technologies and cloud computing[18].

As the energy demands of AI development continue to rise, the need for sustainable and energy-efficient solutions becomes increasingly urgent. While AI has the potential to significantly reduce energy poverty and optimize energy consumption across various sectors, its development and widespread adoption may also contribute to the very problems it seeks to solve[19].

2.1 Energy Efficiency in AI Hardware

The environmental impact of AI development is not limited to the software and algorithms used to train AI models. The hardware used in AI systems, including GPUs, TPUs, and other specialized processors, also plays a crucial role in determining the energy consumption and carbon emissions associated with AI technologies[20]. These hardware components are specifically designed to handle the computationally intensive tasks associated with AI training and inference, and

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[15] A. GONZALEZ-GARAY, C. HEUBERGER-AUSTIN, X. FU, M. KLOKKENBURG, D. ZHANG, A. VAN DER MADE and N. SHAH, *Unravelling the potential of sustainable aviation fuels to decarbonise the aviation sector*, in *Energy & Environmental Science*, 2022, 15 (8);

[16] N. JONES, *How to stop data centres from gobbling up the world's electricity*, in *Nature*, 2018, 561 (7722);

[17] In a 2015 study, Andres Andrae et al. predicted an increase to 20% of the total energy consumption by data centres, which was then revised in a later study to 3%. See both studies respectively A. S. ANDRAE and T. EDLER, *On global electricity usage of communication technology: trends to 2030*, in *Challenges*, 2015, 6 (1); and A. ANDRAE, *Should we be concerned about the power consumption of ICT*, in *Presentation at the Around the World Sustainable Research e-Conference*, 2018;

[18] A. ANDRAE, *Total consumer power consumption forecast*, in *Nordic Digital Business Summit*, 2017, 10

[19] M. COECKELBERGH, *AI for climate: freedom, justice, and other ethical and political challenges*, in *AI and Ethics*, 2021, 1 (1);

[20] W. H. CHEONG, J. B. JEON, J. H. IN, G. KIM, H. SONG, J. AN, J. PARK, Y. S. KIM, C. S. HWANG and K. M. KIM, *Demonstration of Neuromodulation-inspired Stashing System for Energy-efficient Learning of Spiking Neural Network using a Self-Rectifying Memristor Array*, in *Advanced Functional Materials*, 2022, 32 (29);

their energy efficiency can have a significant impact on the overall environmental footprint of AI development[21].

In recent years, there has been a growing emphasis on improving the energy efficiency of AI hardware, with major technology companies investing heavily in the development of more sustainable and power-efficient processors. For example, the introduction of Tensor Processing Units (TPUs) by Google has enabled more energy-efficient AI model training and inference, as TPUs are specifically designed for machine learning workloads and consume less power compared to traditional GPUs[22].

Nevertheless, as AI models become more complex and require more computational resources, the energy efficiency gains achieved by advances in hardware may be offset by the increasing demands of AI development. This highlights the importance of continued innovation in AI hardware to ensure that energy efficiency improvements keep pace with the escalating computational requirements of AI technologies[23].

2.2 The Role of Data in AI's Environmental Impact

The environmental impact of AI development is also influenced by the data used to train and refine AI models. Large-scale AI models, such as deep learning and NLP systems, often rely on vast amounts of data to achieve high levels of accuracy and performance. This data-intensive approach can result in increased energy consumption and carbon emissions, as the process of collecting, storing, and processing vast quantities of data requires significant computational resources[24].

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[21] Ibid.

[22] N. JOUPPI, *Quantifying the performance of the TPU, our first machine learning chip*, 2017, avaliable at https://cloud.google.com/blog/products/gcp/quantifying-the-performance-of-the-tpu-our-first-machine-learning-chip/; For a more in-depth discussion see N. P. JOUPPI, D. H. YOON, G. KURIAN, S. LI, N. PATIL, J. LAUDON, C. YOUNG and D. PATTERSON, *A domain-specific supercomputer for training deep neural networks*, in *Communications of the ACM*, 2020, 63 (7);

[23] P. DHAR, *The carbon impact of artificial intelligence*, in *Nature Machine Intelligence*, 2020, 2 (8);

[24] ibid., OECD, *Measuring the environmental impacts of artificial intelligence compute and applications*, 2022;

Moreover, the iterative nature of AI model training, which involves repeatedly adjusting model parameters based on the input data, further contributes to the environmental impact of AI development. Each iteration requires additional computational resources, and the cumulative energy consumption and carbon emissions associated with multiple iterations can be substantial[25].

One potential solution to this issue is the development of AI models that require less data for training or that can learn more efficiently from the available data[26]. Techniques such as transfer learning, which involves adapting a pre-trained model to a new task with minimal additional training, can help reduce the environmental impact of AI development by leveraging existing resources and minimizing the need for extensive data processing[27].

2.3 The Importance of Sustainable AI Deployment

While much of the focus on the environmental impact of AI development revolves around the training process, it is also crucial to consider the sustainability of AI deployment in real-world applications. The energy consumption and carbon emissions associated with AI model deployment can be significant, particularly for applications that require continuous, real-time processing of large volumes of data.

To minimize the environmental impact of AI deployment, developers and organizations must carefully consider the energy efficiency of their AI systems and

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[25] K. HAO, *Training a single AI model can emit as much carbon as five cars in their lifetimes*, in *MIT technology Review*, 2019, 75

[26] Although this will not be applicable to all instances. For example, robots must acquire new skills and tasks on-site, as it is impractical for designers to pre-embed all the necessary knowledge that a robot may need. See G. ANGELOPOULOS, A. ROSSI, G. L'ARCO and S. ROSSI, *Transparent Interactive Reinforcement Learning Using Emotional Behaviours*, in *ICSR 2022*, 2022; On the importance of personalisation in social robotics, see also I. TARAKLI, G. ANGELOPOULOS, M. HELLOU, C. VINDOLET, B. ABRAMOVIC, R. LIMONGELLI, D. LACROIX, A. BERTOLINI, S. ROSSI and A. DI NUOVO, *Social Robots Personalisation: At the Crossroads between Engineering and Humanities (CONCATENATE)*, in *Companion of the 2023 ACM/IEEE International Conference on Human-Robot Interaction*, 2023;

[27] A. FARAHANI, B. POURSHOJAE, K. RASHEED and HAMID, *A Concise Review of Transfer Learning*, in *2020 International Conference on Computational Science and Computational Intelligence (CSCI)*, 2021;

prioritize the use of sustainable infrastructure and technologies[28]. For example, deploying AI models on energy-efficient hardware and utilizing renewable energy sources for data centres can help reduce the carbon footprint of AI applications[29]. Furthermore, incorporating energy-saving features into AI-driven solutions, such as energy management systems for smart buildings or traffic optimization algorithms for transportation networks, can help offset the environmental impact of AI deployment by contributing to overall energy savings and emissions reductions[30]. However, unless more transparency is achieved, it would be impossible to assess whether an AI-driven solutions is offsetting the environmental impact resulting from its training and deployment[31].

In addition, investing in research and development of sustainable AI technologies is essential for minimizing the environmental impact of AI development. This can be achieved by encouraging research into AI models that need less data for training, thus reducing the computational and energy demands associated with model training and tuning – see for instance Neuromorphic Computing, which compared to traditional approaches is much more energy efficient[32]. It is also important to promote the creation of energy-efficient AI hardware, such as specialized AI accelerators that use less power compared to conventional GPUs or CPUs[33]. Additionally, supporting the exploration of AI-driven solutions that contribute to overall energy savings and emissions reductions is vital, for instance,

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[28] Z. ZHONGMING, L. LINONG, Y. XIAONA, Z. WANGQIANG and L. WEI, *Environmental Impact of Computation and the Future of Green Computing*, 2021, avaliable at https://www.sciencedaily.com/releases/2021/03/210302185414.htm;

[29] D. PATTERSON, J. GONZALEZ, U. HÖLZLE, Q. LE, C. LIANG, L.-M. MUNGUIA, D. ROTHCHILD, D. R. SO, M. TEXIER and J. DEAN, *The carbon footprint of machine learning training will plateau, then shrink*, in *Computer*, 2022, 55 (7);

[30] See for example Z. LV and W. SHANG, *Impacts of intelligent transportation systems on energy conservation and emission reduction of transport systems: A comprehensive review*, in *Green Technologies and Sustainability*, 2022, 1 (1);

[31] For a more in-depth discussion on transparency, accountability and how to achieve them, please refer to sections 3.2 and 3.3 of this paper.

[32] M. AITSAM, S. DAVIES and A. DI NUOVO, *Neuromorphic Computing for Interactive Robotics: A Systematic Review*, in *IEEE Access*, 2022, 10

[33] A. MISHRA, J. CHA, H. PARK and S. KIM, *Artificial Intelligence and Hardware Accelerators*, Springer Nature, 2023;

through the development of smart grid technologies, energy-efficient building design, and enhanced resource management.

To conclude, it can be said the environmental impact of AI development is a multifaceted issue that encompasses a wide range of factors, including carbon emissions from model training, energy consumption of AI hardware, the role of data in AI development, and the sustainability of AI deployment in real-world applications. By understanding and addressing these factors, researchers, developers, policymakers, and industry leaders can work together to develop AI technologies that not only address energy poverty and optimize energy consumption but also minimize their environmental footprint and contribute to a more sustainable future.

3. Policy and Regulatory Frameworks Recommendations for Sustainable AI Development

Policymakers must duly consider the implementation of policy and regulatory frameworks that fortify sustainable AI development, which encompasses several key aspects. As AI technologies become more pervasive and their environmental impact more pronounced, it is essential for policymakers to consider the ethical and sustainable development of AI systems[34]. This involves not only balancing the transformative potential of AI technologies with their environmental consequences but also ensuring that AI solutions are designed and deployed in a responsible and socially beneficial manner[35].

3.1 Strengthening the Concept of Sustainability in the AI Act

[34] M. A. GORALSKI and T. K. TAN, *Artificial intelligence and sustainable development*, in *The International Journal of Management Education*, 2020, 18 (1);

[35] A. JOBIN, M. IENCA and E. VAYENA, *The global landscape of AI ethics guidelines*, in *Nature Machine Intelligence*, 2019, 1 (9);

In 2018 the European Commission (EC) published a communication titled "Artificial Intelligence for Europe"[36], setting out the strategy on regulating AI. The EC has underlined the importance of AI *which is helping us to solve some of the world's biggest challenges: from treating chronic diseases or reducing fatality rates in traffic accidents to fighting climate change or anticipating cybersecurity threats*[37]. The EC has summed up the approach that the EU should take when dealing with AI, as: *a coordinated approach to make the most of the opportunities offered by AI and to address the new challenges that it brings. The EU can lead the way in developing and using AI for good and for all, building on its values and its strengths*[38]. Following up on its promises, the EC on 21 April 2021 published the AI Act[39], a forward-thinking piece of legislation made up of an Explanatory Memorandum, 89 Recitals, 12 Titles, 85 Articles and 9 Annexes. In giving the reasons for the proposal, the EC refers back to the EU commitment in becoming a market leader in relation to AI through making sure that AI developed and marketed in the EU is human-centric, [40].

As AI technologies continue to gain prominence and their potential environmental impact becomes more apparent, it is essential to reinforce the idea of sustainability within the AI Act. Focusing on this issue and offering clear guidance for sustainable AI development, we can help direct the actions of policymakers, researchers, developers, and industry leaders towards environmentally responsible AI practices. In light of the current draft of the AI Act, a piece of legislation dubbed

[36] EUROPEAN COMMISSION, *Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions. Artificial Intelligence for Europe*, European Commission, Brussels, 2018;
[37] Ibid.
[38] Ibid.
[39] A. I. ACT, *Proposal for a regulation of the European Parliament and the Council laying down harmonised rules on Artificial Intelligence (Artificial Intelligence Act) and amending certain Union legislative acts*, 2021;
[40] Paragraph 1.1 of the Explanatory Memorandum of the AI Act: "*The proposal is based on EU values and fundamental rights and aims to give people and other users the confidence to embrace AI-based solutions, while encouraging businesses to develop them. AI should be a tool for people and be a force for good in society with the ultimate aim of increasing human well-being. Rules for AI available in the Union market or otherwise affecting people in the Union should therefore be human centric, so that people can trust that the technology is used in a way that is safe and compliant with the law, including the respect of fundamental rights*".

as human-centric[41] but yet offers little attention to the development of sustainable AI and reduces sustainability to a mere suggestion[42], it is crucial for policymakers to prioritize the incorporation of sustainability into AI development policies, - after all, can any legislation be human-centric without taking in to account sustainability? -, this shall include establishing clear guidelines and requirements for sustainable AI development and providing incentives for organizations that prioritize environmentally responsible AI practices.

The integration of sustainability provisions into AI regulations, such as the AI Act, holds utmost importance. Such integration would establish minimum energy efficiency and emissions reduction standards for AI development and deployment, thereby maintaining the AI industry's environmental consciousness. For instance, mandating organizations to report on energy consumption, carbon emissions, and mitigation measures, policymakers can cultivate a culture of responsibility and environmental stewardship within the AI sector. Several methods have been developed in recent years to help predict and mitigate the environmental impact of AI development and deployment[43]. These methods can provide valuable insights for policymakers seeking to develop sustainable AI policies and guidelines[44]. Some of the most notable include: Carbontracker[45], Machine Learning Emissions Calculator[46] and, Experiment-Impact-Tracker[47]. Therefore, it is suggested that by

[41] EC, *A European approach to artificial intelligence*, European Commission, 2022;. Also see AI Act, *supra* note 39.

[42] See paragraph 5.2.7 of the Explanatory Memorandum of the AI Act. See also Recital 81 and Article 69 of the AI Act. These are the only three instances where sustainability is mentioned within the AI Act.

[43] See for example MLCO2 online calculator https://mlco2.github.io/impact/

[44] E. GARCÍA-MARTÍN, C. F. RODRIGUES, G. RILEY and H. GRAHN, *Estimation of energy consumption in machine learning*, in *Journal of Parallel and Distributed Computing*, 2019, 134

[45] Can be used for tracking and predicting the energy consumption and carbon emissions of training deep learning models. Carbontracker can help researchers and developers understand the environmental impact of their AI models and identify opportunities for reducing energy consumption and emissions. See L. F. W. ANTHONY, B. KANDING and R. SELVAN, *Carbontracker: Tracking and predicting the carbon footprint of training deep learning models*, in *ICML Workshop on "Challenges in Deploying and monitoring Machine Learning Systems"*, 2020;

[46] This tool estimates the carbon footprint of GPU compute by specifying hardware type, hours used, cloud provider, and region. The calculator can help organizations assess the environmental impact of their AI workloads and make more informed decisions about their hardware and infrastructure choices. See A. LACOSTE, A. LUCCIONI, V. SCHMIDT and T.

requiring developers to incorporate these methods into the AI development processes, accountability and transparency will be readily achieved.

3.2 Proportionality and AI Development

There is no doubt that one of the key policy considerations for AI sustainability is the concept of proportionality, which refers to the balance between the benefits of a particular AI method and its potential environmental impact[48].

For instance, policymakers should consider the potential need for constant tuning of AI models as society evolves in its communication, transportation, and social habits. The costs associated with this ongoing tuning process must be factored into any proportionality calculations, and alternative methods such as transfer learning[49] shall be refined and used in order to make such tuning cost effective and limit its impact on the environment.

Furthermore, it may prove necessary to restrict the use of certain AI techniques, such as tuning deep learning NLP models for menial or ethically problematic applications[50]. This could help prevent the unnecessary consumption of computational resources and reduce the environmental impact of AI development. However, the implementation of this approach does present its own set of challenges, such as the need to define what constitutes a "menial" or "ethically problematic" application of AI. Menial application may refer to a use case that is

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DANDRES, *Quantifying the carbon emissions of machine learning*, 2019, avaliable at https://arxiv.org/abs/1910.09700;

[47] Framework for tracking real-time energy consumption and carbon emissions, as well as generating standardized online appendices. This tool can help researchers and developers monitor the environmental impact of their AI projects and implement strategies to reduce energy consumption and emissions. See P. HENDERSON, J. HU, J. ROMOFF, E. BRUNSKILL, D. JURAFSKY and J. PINEAU, *Towards the Systematic Reporting of the Energy and Carbon Footprints of Machine Learning*, in *The Journal of Machine Learning Research*, 2020, 21 (1);

[48] For a more in-depth discussion on the concept of proportionality, refer to section 4 of R. GELLERT, *Introduction: The risk-based approach as the opposite of the rights-based approach, or as an opportunity to analyse the links between law, regulation, and risk?*, in *The Risk-Based Approach to Data Protection*, Oxford University Press, 2020;

[49] See section 2.3 of this paper for an explanation of transfer learning. The idea is that of training a model from existing data rather than from scratch, resulting in less energy consumption thus less carbon emission.

[50] A. VAN WYNSBERGHE, *Sustainable AI: AI for sustainability and the sustainability of AI*, in *AI and Ethics*, 2021, 1 (3);

trivial, does not significantly benefit society, or could be easily addressed by simpler, less resource-intensive methods. For instance, using advanced AI to automate simple tasks that do not require complex intelligence, like turning lights on and off, could be seen as menial because simpler, less energy-consuming solutions exist. Ethically problematic application of AI, on the other hand, may refer to uses of AI that may pose ethical issues or harm to individuals or society such as 'deepfakes'.

Determining what is menial or ethically problematic is a complex task, which involves subjective judgments. It may require a comprehensive framework, extensive debate among stakeholders, and consistent updating and refinement to ensure that the definitions stay relevant with evolving AI technology and societal norms. This in itself is an arduous task, albeit crucial in ensuring that the restrictions applied are justifiable and effective in promoting sustainable AI development.

3.3 Nudging for Energy Efficiency

Lack of adequate information may contribute to a substantial undervaluation of energy efficiency[51]. Nudging, a behavioural economics concept popularised by Thaler and Sunstein[52], can be used to encourage energy efficiency. Subtly guiding consumers' choices without limiting their options or imposing penalties, nudging can effectively promote sustainable behaviour. For instance, an example of a nudge in the EU is the implementation of appliance labels[53]. These labels provide consumers with information on the energy efficiency of various appliances, with the aim of allowing them to make more informed purchasing decisions. The exploration of a certification or labelling system for AI technologies that comply with specified sustainability criteria is warranted. Drawing inspiration from

[51] R. G. NEWELL and J. SIIKAMÄKI, *Nudging energy efficiency behavior: The role of information labels*, in *Journal of the Association of Environmental and Resource Economists*, 2014, 1 (4);

[52] R. H. THALER and C. R. SUNSTEIN, *Nudge: Improving decisions about health, wealth, and happiness*, Penguin, 2009;

[53] *Regulation (EU) 2017/1369 of the European parliament and of the council of 4 July 2017 setting a framework for energy labelling and repealing directive 2010/30/EU*, 2017;

existing energy efficiency labels for appliances, such a system would facilitate informed choices about AI products and services for consumers and businesses. Empowering the end-users of AI technologies to select environmentally responsible solutions, policymakers can create market-driven demand for sustainable AI development. In turn, possibly this heightened demand for energy-efficient appliances incentivizes manufacturers to innovate and develop more sustainable products, fostering a cycle of continuous improvement in energy efficiency within the market[54]. However, the current EU energy labelling system for appliances is found to be ineffective as the grading systems is hard to comprehend for the average consumer[55]. In fact, it was determined that straightforward information regarding the monetary value of energy savings played a crucial role in guiding cost-effective energy efficiency investments. Furthermore, data on physical energy consumption and carbon dioxide emissions were found to be of secondary importance, albeit still contributing to informed decision-making in the realm of energy efficiency. As such, it is imperative to emphasize the dissemination of accurate and relevant information to ensure well-founded investments in energy-efficient initiatives[56].

Nevertheless, nudges are not perfect and sometimes fail. When that happens, a solution can be that of offering economic incentives[57], encompassing tax breaks, grants, or other financial support, can effectively motivate organizations to invest in sustainable AI technologies and practices, possibly replacing obsolete and high energy consuming technology with more sustainable and low-carbon alternatives[58]. Rendering it financially beneficial for companies to adopt eco-friendly AI solutions,

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[54] A. ROGER, *Outlook: Can Environmental Product Standards Enable Eco-Innovation?*, in *New Developments in Eco-Innovation Research*, 2018;

[55] A. DE AYALA and M. D. M. SOLÀ, *Assessing the EU Energy Efficiency Label for Appliances: Issues, Potential Improvements and Challenges*, in *Energies*, 2022, 15 (12); Sunstein also provides some insight on why nudges might fail, and suggests that a solution is simply to nudge better C. R. SUNSTEIN, *Nudges that fail*, in *Behavioural public policy*, 2017, 1 (1);

[56] R. G. NEWELL and J. SIIKAMÄKI, *Nudging energy efficiency behavior: The role of information labels*, in *Journal of the Association of Environmental and Resource Economists*, 2014, 1 (4);

[57] C. R. SUNSTEIN, *Nudges that fail*, in *Behavioural public policy*, 2017, 1 (1);

[58] M. BROWN, *Innovative energy-efficiency policies: an international review*, in *Wiley Interdisciplinary Reviews: energy and environment*, 2015, 4 (1);

policymakers can stimulate innovation and promote the widespread adoption of sustainable technologies.

3.4 Standardization and Knowledge Sharing

Standards are useful instruments which aim at codifying industry good practice with the aid of industry experts and academics. In fact, due to their well-structured and widely recognized nature, standards serve as crucial contributors to the formulation of national and international regulations. Presently, they hold a pivotal position in the policy-making processes of the EU and its member states[59]. Through the collaborative efforts of stakeholders from various sectors, standardization promotes the establishment of shared understanding and accountability, which are essential for fostering sustainable AI development. Moreover, standardization serves as a valuable reference for policymakers and legal professionals involved in the creation of AI-related laws and policies. Integrating the principles and guidelines outlined in standardized frameworks, legal instruments can more effectively address the complex challenges associated with AI technologies, ensuring adherence to the highest standards of environmental sustainability, ethical responsibility, and social equity.

A prime example of an existing standard that fosters sustainable AI development is the ISO/IEC JTC 1/SC 42 series of standards[60]. This series focuses on AI and its various aspects, including trustworthiness, robustness, and transparency. However, the first standard specific to the environmental sustainability of AI, is currently at the early stages of the development process, the ISO/IEC AWI TR 20226 Information technology — Artificial intelligence — Environmental sustainability aspects of AI systems[61].

The utilization of standards can be advantageous in various ways, such as increasing credibility among consumers, facilitating access to protected markets,

[59] A. XENIAS, *The New Global Rulers: The Privatization of Regulation in the World Economy*, in *Political Science Quarterly*, 2012, 127 (3);

[60] I. ISO and I. JTC, *1/SC 42 Artificial intelligence subcommittee website at www.iso.org*,

[61] I. ISO and I. JTC, *ISO/IEC AWI TR 20226*
Information technology — Artificial intelligence — Environmental sustainability aspects of AI systems,

enabling participation in public procurement, and enhancing efficiency, coordination, and cooperation[62]. Consequently, adherence to standards may offer a competitive edge to businesses.

Nonetheless, standardization can result in the privatization of soft law[63]. Access to international standards, such as those developed by the International Organization for Standardization (ISO), is often restricted by payment of a fee. In addition, the complexity of these standards frequently necessitates the engagement of expert consultants to ensure compliance. This barrier to entry can disproportionately affect smaller actors who may struggle to afford compliance with such standards, thereby limiting their ability to compete effectively in the market. The privatization of soft law through the use of standards can also possibly lead to an uneven playing field, as larger, well-funded organizations are more likely to have the resources to comply with these standards and capitalize on the benefits they offer[64]. Consequently, this is likely to perpetuate existing power imbalances, hinder innovation, and hamper the development of environmentally sustainable AI.

It is crucial to recognize and address these concerns while acknowledging the potential benefits of standardization. Policymakers, standard-setting organizations, and stakeholders must work collaboratively to ensure that the development and implementation of standards for AI are equitable and accessible to all actors, regardless of their size or financial resources.

4. Conclusion

As the development and deployment of AI technologies continue to accelerate, it is essential to recognize and address the environmental, economic, and ethical implications of this powerful and transformative technology. While AI has demonstrated significant potential in tackling global challenges such as energy

[62] E. F. VILLARONGA, *Robots, standards and the law: Rivalries between private standards and public policymaking for robot governance*, in *Computer Law & Security Review*, 2019, 35 (2);

[63] E. F. VILLARONGA and A. ROIG, *European regulatory framework for person carrier robots*, in ibid.2017, 33 (4);

[64] A. BERTOLINI and R. LIMONGELLI, *Regulatory frameworks and standars for agricultural robotics in the European Union*, in *Advances in Agri-food Robotics*, Burleigh Dodds Science Publishing Limited, Forthcoming Q1 2024;

poverty, it is crucial to ensure that its development and application are sustainable, minimizing its environmental impact and maximizing its benefits for society.

This paper has explored various aspects of sustainable AI development, including the environmental impact of AI, policy considerations for AI sustainability, the economics of AI model tuning, and the role of AI in addressing energy poverty. In conclusion, the pursuit of sustainable AI development is a multifaceted and complex endeavour that requires the concerted efforts of policymakers, industry stakeholders, researchers, and educators. Through a holistic and interdisciplinary approach, we can harness the transformative potential of AI in an environmentally responsible and equitable manner, ensuring that AI technologies contribute to a more sustainable, inclusive, and prosperous future for all.

It is essential to acknowledge the potential challenges and risks associated with the widespread adoption of AI in the energy sector. While AI promises significant benefits for addressing energy poverty, it is crucial to consider issues such as data privacy, algorithmic bias, and the environmental impact of AI development. To ensure that AI serves as a force for good in the fight against energy poverty, a comprehensive and balanced approach must be taken, with a focus on promoting sustainability, equity, and inclusivity. The future of AI and energy poverty is marked by both opportunities and challenges. Leveraging the transformative potential of AI technologies, allows to make significant strides towards alleviating energy poverty and ensuring a more sustainable and equitable energy future for all. However, it is crucial to approach this goal with caution, carefully considering the potential risks and drawbacks associated with AI's widespread deployment in the energy sector.

In conclusion, this paper has presented a series of clear and cogent recommendations. The conspicuous absence of dialogue between the academic community and policymakers regarding this critical issue is indeed disconcerting. It is the author's hope that this work will contribute to increased awareness and discussion surrounding sustainable AI development, ultimately leading to its comprehensive consideration by the pertinent institutions.