Vodafone Institute
for Society and
Communications

THE AI GAMBIT

Leveraging artificial intelligence to combat climate change: opportunities, challenges, and recommendations

Summary of a research paper by
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Content

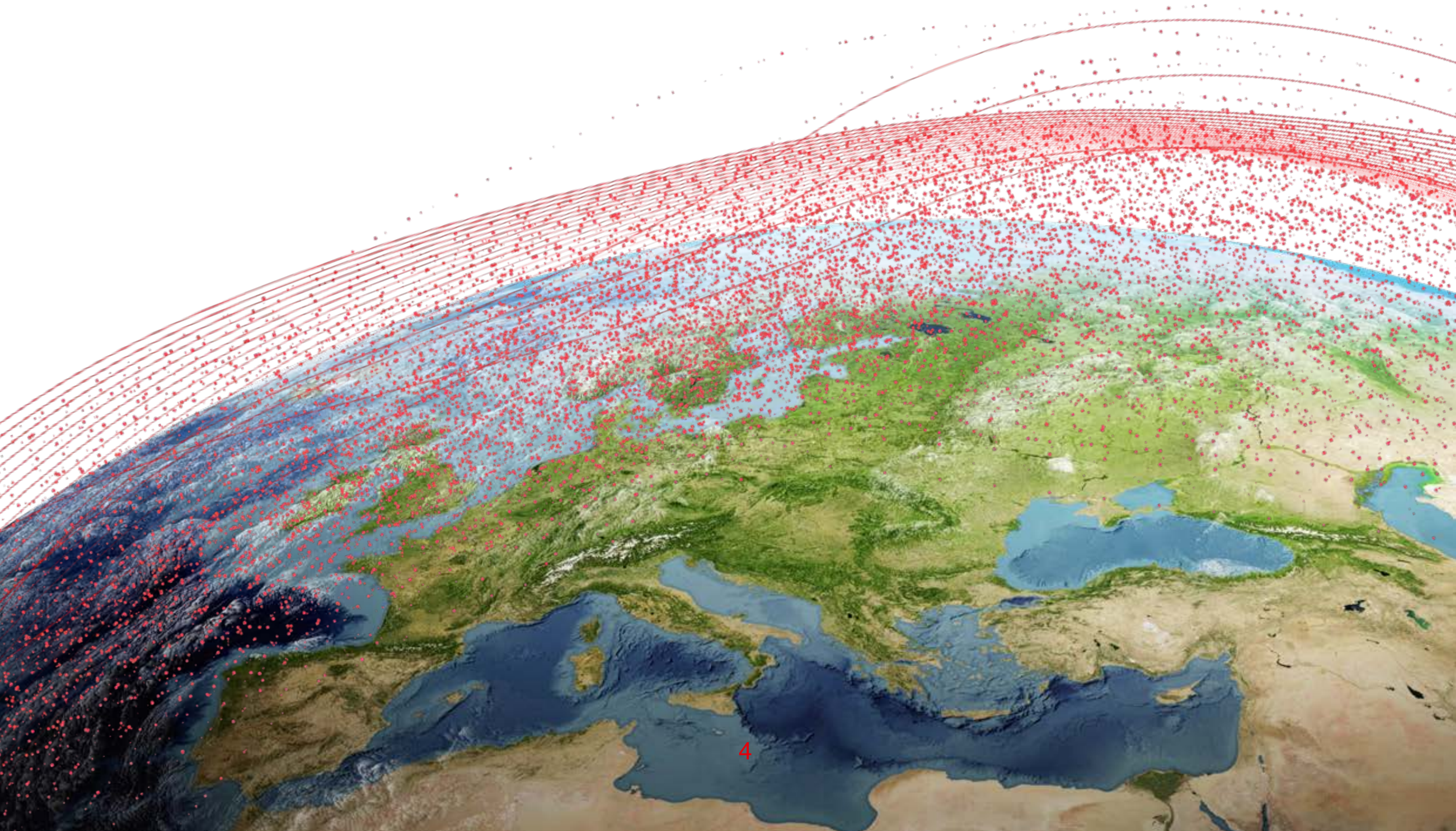
Preamble

Artificial intelligence (AI) can be an extremely powerful tool in the fight against global warming. But there are significant pitfalls, both ethical and environmental, that must be avoided. Understanding them is crucial to this end, and concrete policy steps can help.

The following paper is the product of a collaboration between the Vodafone Institute and a team of researchers at the University of Oxford consisting of Prof. Luciano Floridi, who is also a member of the Vodafone Institute's advisory board, Prof. Mariarosaria Taddeo, and Josh Cowls and Andreas Tsamados, the main authors of the upcoming research paper upon which the present paper is based. The paper's aim is to provide policy recommendations for a path toward a greener and more climate-friendly Europe through the use of more sustainable and equitable AI. The timing is critical because AI is already used today to model events relating to climate change and to contribute to efforts in combating global warming.

More specifically, AI presents two crucial opportunities. The first is scientific: AI can help improve and expand our current understanding of climate change by making it possible to process immense volumes of data to understand existing climate trends and to forecast future developments and the impact of policies. The second is pragmatic: AI can help deliver greener and more effective solutions, such as improving and optimising energy generation and use.

However, there are two main challenges associated with developing AI to combat climate change. One pertains to AI in general: the possible exacerbation of some social and ethical challenges already associated with AI, such as unfair bias, discrimination or opacity in decision making. The other is specific to climate change and is less understood: the contribution to global climate change due to greenhouse gases emitted by training data and computation-intensive AI systems. The current lack of information about the source and amount of energy used in researching, developing and deploying AI models makes it difficult to define exactly the carbon footprint of AI. To overcome this challenge, this report looks specifically at the carbon footprint of AI research and the factors that influence the greenhouse gas emissions of AI at the research and development stage. It also looks at the lack of scientific evidence concerning the trade-off between the emissions required to research, develop and deploy AI, and the energy and resource efficiency gains that AI can offer. Based on these findings, the paper concludes with 13 recommendations for policy makers and AI researchers and developers, which are designed to identify and harness the opportunities of AI for combatting climate change, while reducing the impact of its development on the environment.



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The Green and The Blue: AI and the EU’s “Twin Transitions”

In early pronouncements, European Commission President Ursula von der Leyen has embraced the digital and ecological "twin transitions" that will shape our future. High-level policy documents highlight how EU digital initiatives like "A Europe Fit for the Digital Age", including AI, and ecological goals such as the "European Green Deal" may converge, suggesting a helpful starting point for policymaking. The need for financial stimulus resulting from the coronavirus pandemic has also opened up avenues for tailoring public assistance to promote these "twin transitions."

The Commission sees the two transitions as being deeply interrelated, to the point that the "European Green Deal" proposal is full of references to the role of digital tools, with the roadmap released in December 2019 noting that "digital technologies are a critical enabler for attaining the sustainability goals of the Green Deal in many sectors," and explicitly states that technologies "such as artificial intelligence (…) can accelerate and maximise the impact of policies to deal with climate change and protect the environment" – specifically in the areas of energy grids, consumer products, pollution monitoring, mobility, and food and agriculture. The approach of the Commission resonates with the idea of Floridi and Nobre of a "a new marriage between the Green of our habitats […] and the Blue of our digital technologies […]". The use of AI to fight climate change is a leading example of such a marriage.

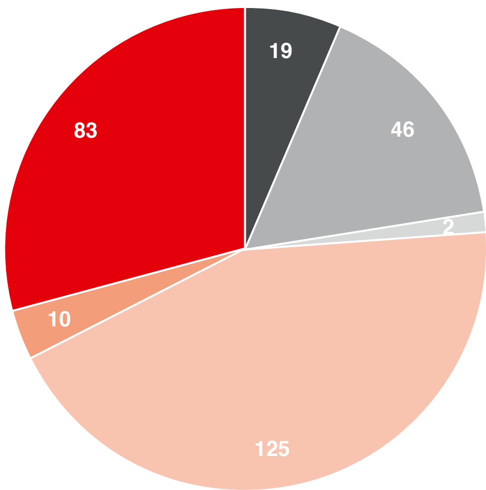
Finally, many of the documents produced by the Commission to flesh out its digital and environmental vision make reference to artificial intelligence as a key tool, particularly with reference to "Destination Earth," an ambitious plan to create a digital model of the Earth and simulate human activity as a way to test the potential effectiveness of Europe's environmental policies. AI is explicitly mentioned as a key component of the Destination Earth initiative.

How AI Is Already Being Used

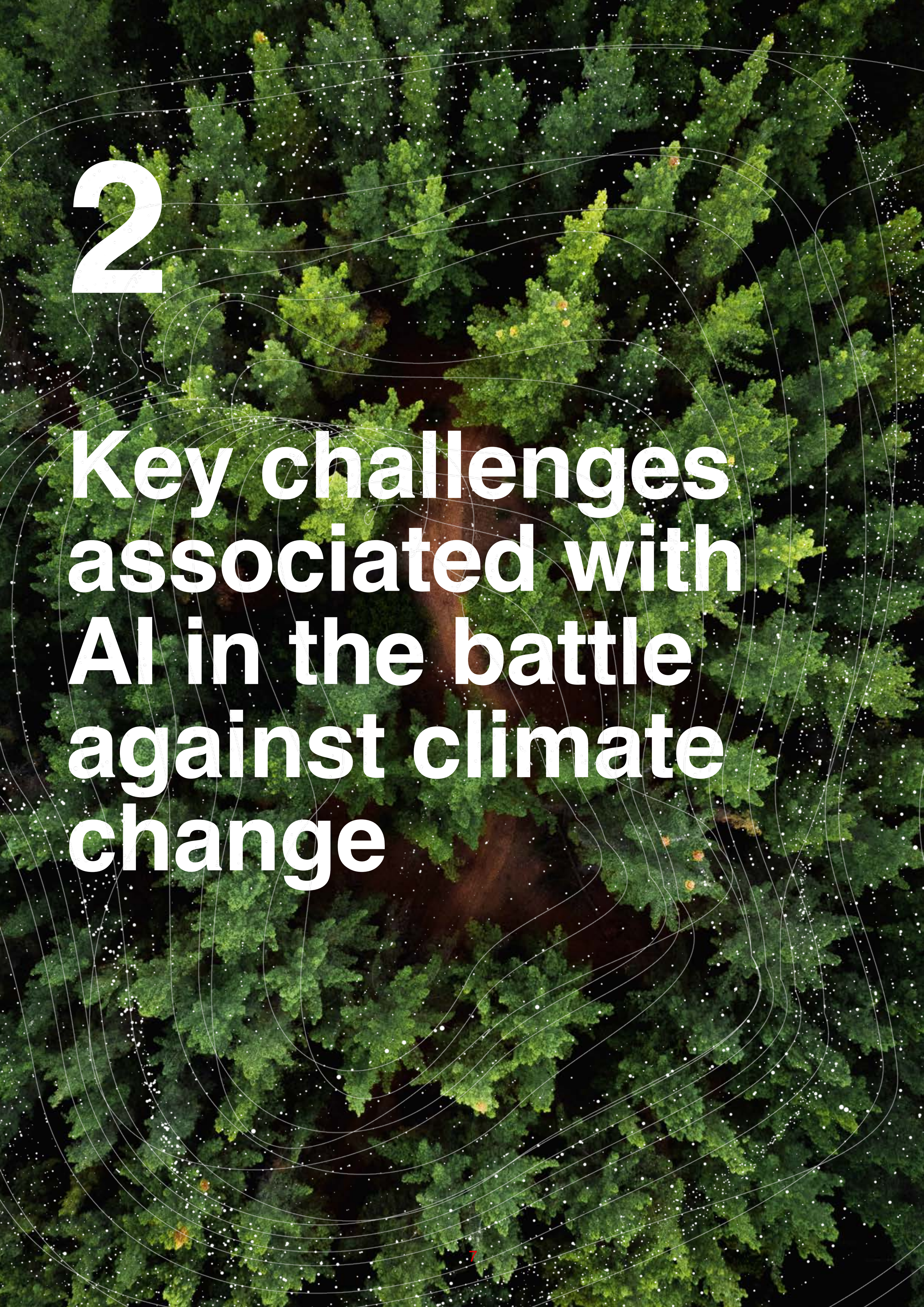
AI techniques have been used to forecast global mean temperature changes, predict climactic and oceanic phenomena like El Niño, and to understand aspects of the weather system both in general and in specific locations. AI tools can also help anticipate extreme weather events that climate change has made more common.

AI can also make proactive contributions to the fight against global warming. The technology can be used to boost energy efficiency in heavy industry, to evaluate the carbon footprint of cement used in construction or improve electrical grid management. AI can be used to predict the impact of carbon taxes or to help monitor sequestration efforts. Indeed, a search of Cordis – the European database for funded research – turned up 122 projects across the Continent using AI to address aspects of climate change in a variety of different areas.

Disciplinary focus of EU-funded projects using AI to address climate change:



19 Agricultural sciences
46 Engineering and technology
2 Humanities/philosophy
125 Natural sciences
10 Medical and health sciences
83 Social sciences



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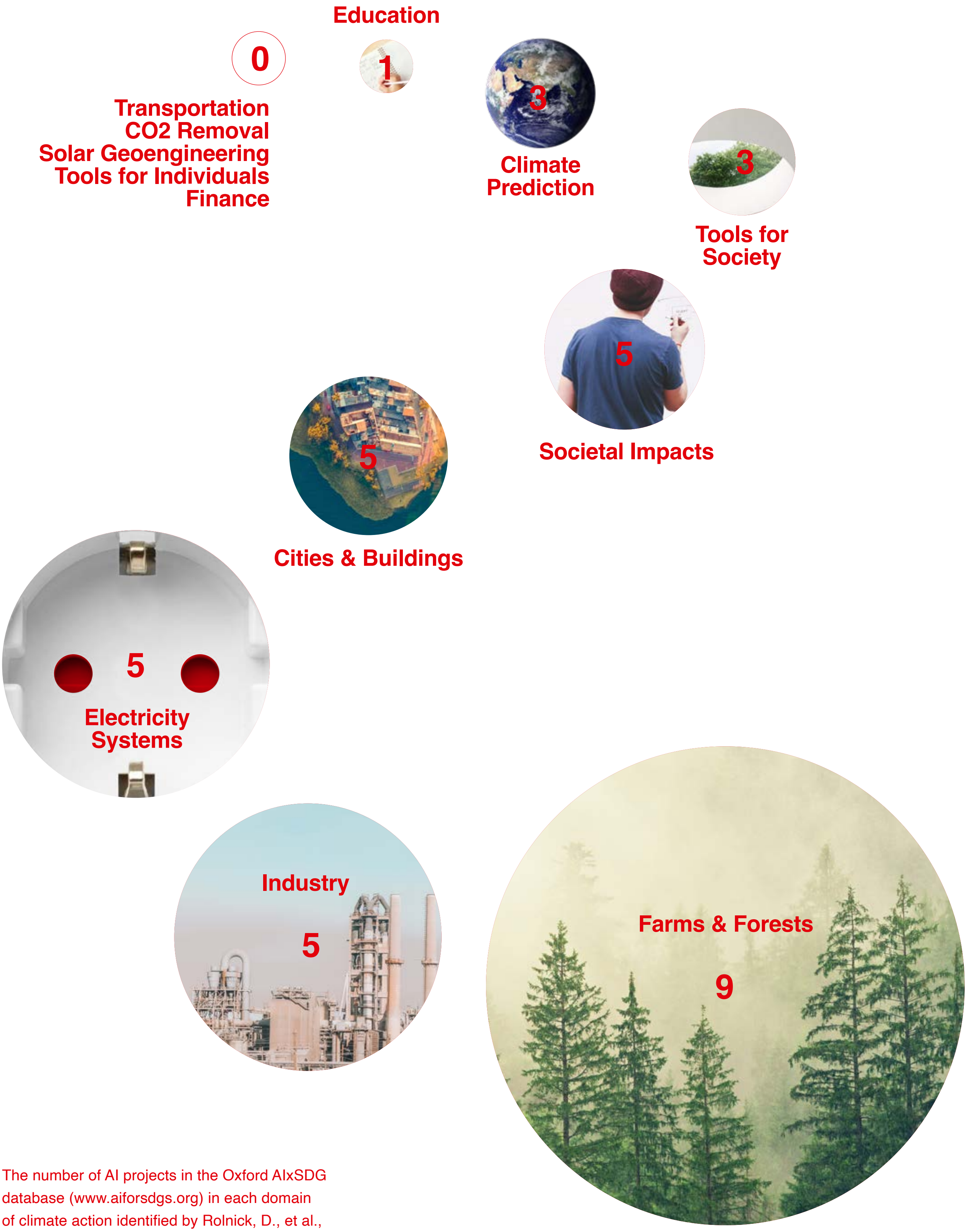
Key challenges associated with AI in the battle against climate change

For all the documents that have been produced by the European Commission in which AI has been identified as a key tool, and for all the opportunities they highlight, they tend to overlook the challenges that must be addressed to ensure a successful and sustainable adoption of AI tools. From ethical and privacy concerns to the significant amount of energy that goes into training and deploying AI tools, understanding and taking steps to address those challenges is crucial to ensuring the sustainability of AI deployment in the battle against global warming.

Identifying where AI is already being used

The first challenge facing any effort to elucidate the role that AI can play in combating climate change is determining where the technology is already being used. A number of efforts have been made to create an accurate overview of how AI is being harnessed around the world in climate projects, but the rapid pace of the technology's development has inevitably limited the accuracy of any single survey. Some approaches have focused on the United Nations Sustainable Development Goals (SDGs) – particularly those dealing most specifically with climate-related issues – as a starting point to identify artificial intelligence projects. A database assembled by the University of Oxford's Research Initiative on AIxSDGs includes 28 projects related to Goal 13, which most specifically focuses on climate change. Other databases using the SDGs as a starting point, however, contain far fewer projects, a testament to the work that still needs to be done to improve the understanding of the many climate-related areas where AI has been deployed. The large-scale 2019 study "Tackling Climate Change with Machine Learning" by Rolnick and colleagues sought to go beyond the relatively specific focus on SDGs and identified 35 use cases across 13 domains.



The number of AI projects in the Oxford AIxSDG database (www.aiforsdgs.org) in each domain of climate action identified by Rolnick, D., et al., 2019, “Tackling Climate Change with Machine Learning”. arXiv:1906.05433

Ethical pitfalls associated with artificial intelligence

A second key challenge involves the ethical risks associated with AI more broadly. Even if such risks are far more significant in areas such as healthcare and criminal justice – where data privacy is crucial and decisions have a far greater impact on individuals – it is nevertheless vital to minimise the ethical risks that may arise when applying AI solutions to climate change.

Because AI models are "trained" using existing datasets, there is a potential for introducing bias into such models due to the datasets chosen for training. Imagine, for example, deploying AI to determine where to set up charging stations for electric vehicles. Using the existing driving patterns of electric cars could skew the data toward a wealthier demographic due to the relatively higher prevalence of electric vehicle use among higher income brackets. That, in turn, would create an additional hurdle to increasing electric car use in less wealthy areas.

Another potential ethical pitfall concerns the erosion of human autonomy. Tackling climate change requires large-scale coordinated action, including systemic changes to individual behaviour. A careful balance must be struck here between protecting individual autonomy and implementing large-scale climate-friendly policies and practices.

The third challenge involves protecting individual privacy. While many AI solutions deployed in the battle against climate change rely on non-personal data, such as meteorological and geographical data, some strategies for limiting emissions may require data pertaining to human behaviour. This tension is highlighted in a recent Vodafone Institute research finding showing that, while Europeans are broadly willing to share their data to help protect the environment, a clear majority (53 per cent) would only do so under strict conditions of data protection.

The carbon footprint of AI

Perhaps the greatest challenge associated with the use of AI in addressing climate change is assessing and accounting for the carbon footprint of the technology itself. After all, it is of little help if AI solutions contribute to alleviating one aspect of climate change while exacerbating another.

Put simply, a significant share of the carbon footprint generated by AI is associated with the computing power necessary to train machine learning systems. Such systems are trained by being fed vast quantities of data, which requires correspondingly powerful data centres. And those data centres need energy to operate. Furthermore, since the advent of deep learning, a type of machine learning that involves algorithms learning from huge amounts of data, the computing power required for model training has doubled every 3.4 months, resulting in growing energy demand. The increase in energy consumption associated with training larger models and with the widespread adoption of AI has been in part mitigated by hardware efficiency improvements. However, depending on where and how energy is sourced, stored and delivered, the rise of compute-intensive AI research can have significant, negative environmental effects

The increasing availability of massive quantities of data has been a major factor fuelling the rise of AI. So, too, have new methods designed to leverage Moore's law, according to which microchip performance doubles every two years. The introduction of chips with multiple processor cores massively accelerated that development. This innovation has enabled the development of increasingly complex AI systems, but it has also significantly increased the amount of energy needed to research, train and operate them. In the publication "The Computational Limits of Deep Learning", Neil C. Thompson, Kristjan Greenewald, Keeheon Lee and Gabriel F. Manso illustrate the growing demand of computing power through deep learning.

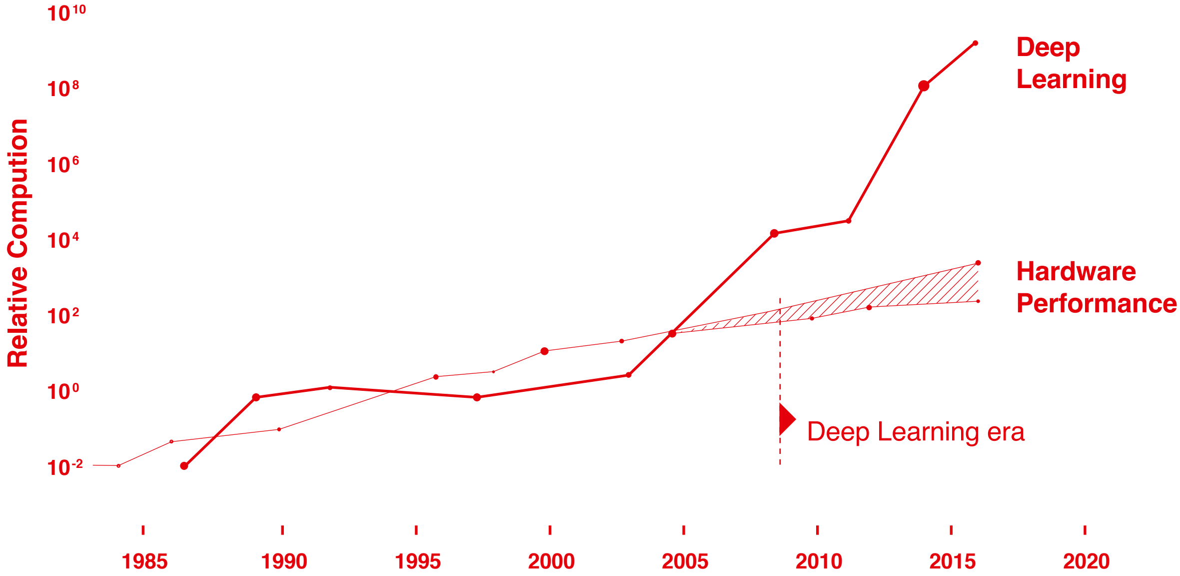
Calculating carbon impact

GPT-3 is an autoregressive language model that uses deep learning to produce human-like text. According to documentation published in May 2020, it required an amount of computational power (compute) several orders of magnitude higher than its predecessor GPT-2, published only one year prior.

Based on the amount of compute and type of hardware used to train GPT-3 and making assumptions as to the rest of the training infrastructure, we estimate using Lacoste et al.'s carbon impact calculator that a single training run of GPT-3 using Microsoft Azure in the United States would have produced 223,920 kilograms of CO2 (or equivalent – CO2eq). Had the cloud provider been Amazon Web Services (AWS), 279,900 kilograms of CO2eq would have been generated (this does not include carbon offsetting efforts made by these companies). By comparison, a typical passenger car in the U.S. emits about 4,600 kilograms of CO2eq per year, meaning a single training run would emit as much as 49 cars (Microsoft Azure) or 61 cars (AWS) do in a year.

Furthermore, geography is important. It is 10 times more costly in terms of CO2eq emitted to train a model using energy grids in South Africa than in France, for example.

Computing Power demanded by Deep Learning



The amount of computational power (compute) demanded by AI is rising quickly. Source: Thompson, Neil C., Kristjan Greenewald, Keeheon Lee, and Gabriel F. Manso. 2020. „The Computational Limits of Deep Learning“. ArXiv:2007.05558 [Cs, Stat], July.

This development is hardly a secret, and major data centre operators, such as cloud providers like Microsoft and Google, have taken significant steps to reduce their carbon footprint by investing in energy-efficient infrastructure, switching to renewable energy, recycling waste heat, and other similar measures. The International Energy Agency reports that, if current efficiency trends in hardware and data centre infrastructure can be maintained, global data centre energy demand – currently 1 per cent of global electricity demand – “can remain nearly flat through 2022, despite a 60 per cent increase in service demand.”

Still, one issue here is the lack of transparency regarding the data required to calculate greenhouse gas emissions of on-premise data centres as well as cloud vendors. Furthermore, calculating the carbon footprint of AI involves more than just data centres. Therefore, it remains unclear whether increased energy efficiency at data centres will offset the rapidly rising demand for computational power, nor is it clear whether such efficiency gains will be realised equally around the world.

For all these reasons, it is crucial to assess the carbon footprint of various AI solutions used in different aspects of understanding climate change or in developing strategies to address certain aspects of it. But this, too, is problematic. Easy to use techniques to monitor and control the carbon emissions of AI research and development are only now beginning to appear. However, some approaches seem promising. The goal is to track several factors during model training phases to help assess and control emissions. The factors include the type of hardware used, the training duration, the energy resources used by the energy grid supplying the electricity, memory usage and other factors.

Nevertheless, even lower hurdles in reducing AI's carbon footprint are difficult to clear due to the lack of widespread adoption of such approaches and thus to the lack of information in many AI research publications. That can also lead to unnecessary carbon emissions when other researchers seek to reproduce the results of AI studies. Some papers don't disclose their code, while others provide insufficient information about the training conditions of their models. Additionally, the number of experiments run by researchers before achieving publishable results is underreported. Some experiments require the training of thousands of models during research and development phases only to achieve modest performance improvements. Massive amounts of computational power can go into fine-tuning. One example here is a research paper by Google Brain, which described the training of over 12,800 neural networks in order to achieve a 0.09 percent improvement in accuracy. Modern AI research has tended to focus on producing deeper and more accurate models at the detriment of energy efficiency.

But the field needs to reconsider its dedication to compute-intensive research for its own sake, and to move away from performance metrics that focus exclusively on accuracy improvements.

Focusing heavily on accuracy over efficiency improvements tends to create a high barrier to entry, since only wealthy research groups can afford the computational power required. Research teams from smaller organisations or those in developing countries are thus side-lined. It also institutionalises a "the bigger the better" attitude and incentivises incremental improvements, even if they are negligible in terms of practical utility.

Some researchers are seeking to lower the computational burden and energy consumption of AI through algorithmic improvements and building more efficient models. And it is also vital to consider that many AI models, even if training them is energy intensive, alleviate or replace tasks that would otherwise require more time, space, human effort and even energy. But the field needs to reconsider its dedication to compute-intensive research for its own sake, and to move away from performance metrics that focus exclusively on accuracy improvements.

The EU has a vital role to play here. Given the positive role AI can have in the battle against climate change, and given Europe's goals on both climate change and digitisation, the EU would be a perfect sponsor in addressing the complexities associated with the technology's own contribution to the problem and in meeting the need for coordinated, multilevel policymaking to ensure the successful adoption of AI solutions.

3

Harnessing the opportunities of AI for combating climate change: recommen-dations

The following recommendations focus on the two broad objectives suggested above. First, harnessing the opportunities presented by AI to combat climate change in ways that are ethically sound. And second, minimising the size of AI's carbon footprint. The recommendations urge all relevant stakeholders to assess existing capacities and potential opportunities, incentivise the creation of new infrastructure, and develop new approaches to allow society to maximise the potential of AI in the context of climate change, while minimising ethical and environmental drawbacks.

Promoting ethical AI in the battle against climate change

Performing comprehensive surveys and holding global conferences does not seem sufficient to gather, document and analyse the use of AI to combat climate change. More needs to be done to identify and promote such efforts. The recent European Strategy for Data notes that a current lack of data also hinders the use of data for the public good. There is a need for legislative and regulatory steps to encourage business-to-business and business-to-government data sharing to promote the development of more and better AI-based solutions, either as for-profit products and services or as efforts to tackle climate-related issues without a profit incentive.

Furthermore, given the EU´s goals on both climate change and digitisation, the EU would be an ideal sponsor of such incentivisation efforts. With the agreement that parts of the Recovery and Resilience Facility, the EU's coronavirus recovery fund, should specifically be dedicated to combat climate change and to promote digital transition, there seems to be plenty of scope for these recommendations to become reality. The EU is also perfectly positioned to ensure steps are taken to prevent bias and discrimination from creeping into AI tools and to ensure that AI metrics are transparent to all stakeholders.

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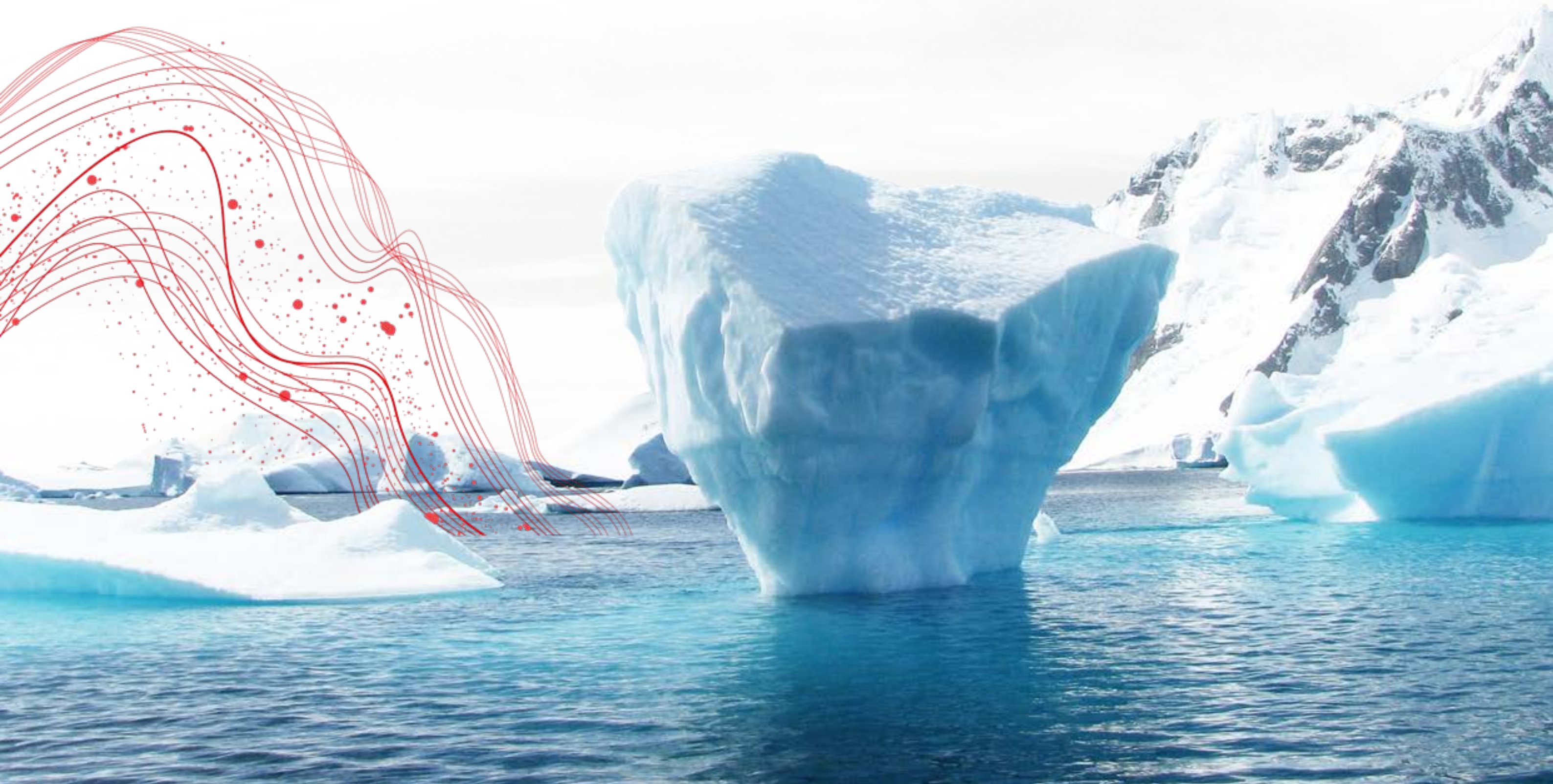

Recommendations

1

Incentivise a world-leading initiative (an Observatory) to document evidence of AI being used to combat climate change around the world; derive best practices and lessons learned; and disseminate the findings among researchers, policymakers and the public.

2

Develop standards of quality, accuracy, relevance and interoperability for data to be included in the forthcoming Common European Green Deal data space; identify aspects of climate action for which more data would be most beneficial; and explore, in consultation with domain experts and civil society organisations, how these data could be pooled in a common global climate data space.

3

Incentivise collaborations between data providers and technical experts in the private sector with domain experts from civil society, in the form of “challenges”, to ensure that the data in the Common European Green Deal data space are utilised effectively against climate change.

4

Incentivise the development of sustainable, scalable responses to climate change that incorporate AI technology, drawing on earmarked Recovery and Resilience Facility resources.

5

Develop mechanisms for ethical auditing of AI systems deployed in high-stakes climate change contexts, where personal data may be used and/or individual behaviour may be affected. Ensure that clear, accessible statements regarding what metrics AI systems are optimised for, and why this is justified, are made available prior to the deployment of these systems. The possibility for affected stakeholders to question and contest system design and outcomes should also be guaranteed.

Gauging and auditing the carbon footprint of AI: researchers and developers

There are many immediate steps that can be taken by those in the research and development field to ensure that the carbon footprint of AI is both properly gauged and kept in check. Indeed, many steps have already been taken, such as encouraging paper submissions to include source code to ensure reproducibility. Systematic and accurate measurements to evaluate the energy consumption and carbon emissions of AI are also needed for research activities. Recommendations 6 and 7 are key to normalising the disclosure of information pertaining to the carbon footprint of AI and enabling researchers and organisations to include environmental considerations when choosing research tools.

Recommendations

6

Develop conference and journal checklists that include the disclosure of, inter alia, energy consumption, computational complexity, and experiments (e.g., number of training runs, and models produced) to align the field on common metrics.

7

Assess the carbon footprint of AI models that appear on popular libraries and platforms, such as PyTorch, TensorFlow and Hugging Face, to inform users about their environmental costs.

8

Incentivise the development of efficiency metrics for AI research and development (including model training) by promoting efficiency improvements and objectives in journals, conferences and challenges.

Gauging and controlling the carbon footprint of AI: policymakers

Policymakers also have a vital role to play in levelling the playing field when it comes to accessing computational power and making AI research more accessible and affordable. One example in this regard is the proposal by researchers in the United States to nationalise cloud infrastructure to give more researchers affordable access. A European equivalent could enable researchers in the EU to compete more effectively on a global scale while ensuring that such research takes place on an efficient and sustainable platform.

Recommendations

9

Develop greener, smarter and cheaper data infrastructure (e.g., European research data centres) for researchers and universities across the EU.

10

Assess AI and its underlying infrastructure (e.g., data centres) when formulating energy management and carbon mitigation strategies to ensure that the European AI sector becomes sustainable as well as uniquely competitive.

11

Develop carbon assessment and disclosure standards for AI to help the field align on metrics, increase research transparency, and communicate carbon footprints effectively via methods such as adding carbon labels to AI-based technologies and models listed in online libraries, journals, and leader boards.

12

Incentivise diverse research agendas by funding and rewarding projects that diverge from the current trend of compute-intensive AI research in order to explore energy-efficient AI.

13

Incentivise energy-efficient and green research by making EU funding conditional on applicants measuring and reporting their estimated energy consumption and GHG emissions. Funding could fluctuate according to environmental efforts made (e.g. usage of efficient equipment, usage of renewable electricity, Power Usage Effectiveness of <1.5).

4

Conclusion

The potential impact of AI in the fight against climate change is significant. But it is more necessary than ever to identify and mitigate the potential environmental pitfalls associated with the technology. The European Union's commitment to both combating climate change and promoting the digital transition opens up vast opportunities to make sure that AI can realise its potential. The right policies are crucial. But if they are identified and implemented by policymakers, it will be possible to harness the power of AI while mitigating its negative impact – and pave the way for a more sustainable society and a healthier biosphere.

Imprint

A summary of the research paper

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