Chapter 12
Advancing Green Artificial Intelligence:
Strategies for a Sustainable Future

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ABSTRACT

Green artificial intelligence (AI) is designed to be more eco-friendly and accessible compared to traditional AI. It delivers precise results without the added computational costs and allows researchers with just a laptop to conduct high-quality work without the need for expensive cloud servers. This chapter explores green AI as a crucial method for improving the environmental sustainability of AI systems. It covers AI solutions that promote eco-friendly practices in various fields (referred to as "green-by AI"), methods for developing energy-efficient machine learning (ML) algorithms and models (known as "green-in AI"), and tools for accurately measuring and optimizing energy usage. The chapter also looks at how regulations can support green AI and discusses future directions for sustainable ML. It highlights

DOI: 10.4018/979-8-3373-0766-4.ch012

the need to integrate environmental considerations into AI practices to promote a more eco-conscious and energy-efficient future for AI technologies.

1. INTRODUCTION

In recent years, artificial intelligence (AI) and machine learning (ML) have transformed many industries by significantly improving efficiency and accuracy in fields such as healthcare, finance, transportation, education, and entertainment. To enhance performance, ML models have become more complex, resulting in a greater number of parameters to estimate. However, these advancements come with increased resource demands, as training and operating these models now require substantial computational power, energy, and water for cooling data centers that store vast amounts of training data, as illustrated in Figure 1.

Despite the exponential growth in data needs and the rising number of hyper parameters over the past decade, improvements in model accuracy have not kept pace. Nevertheless, AI holds great promise for advancing sustainable and efficient solutions, which can support countries in transitioning to cleaner and more sustainable practices. To fully realize this potential, it is crucial to assess sustainability metrics that enhance transparency in model results, including performance, accuracy, and environmental impact, such as energy and water consumption (for example, through the use of ML emissions calculators). It is projected that by 2030, the energy consumption of ML models could account for over 30% of the world's total energy use. Large language models (LLMs), such as the recent GPT-4, exacerbate this issue with their high energy demands. Estimates indicate that training GPT-3 on a dataset of 500 billion words consumed 1287 MWh of electricity and 10,000 computer chips, equivalent to the yearly energy usage of about 121 homes in the US. This process also generated approximately 550 tons of carbon dioxide, comparable to flying 33 times from Australia to the UK. Given that GPT-4 was trained on 570 times more parameters than GPT-3, its energy requirements were even higher. The environmental impact extends beyond training, as using these systems also consumes significant energy. For instance, GPT-3 was accessed 590 million times in January 2023, resulting in energy consumption equivalent to that of 175,000 people. Each query to ChatGPT during inference consumes energy comparable to running a 5 W LED bulb for 1 hour and 20 minutes, totaling 260.42 MWh per day.

The growing environmental impact of these technologies has sparked concerns about their carbon footprint, leading to the emergence of green AI. This new paradigm focuses on incorporating sustainable practices and techniques in the design, training, and deployment of AI models to reduce their environmental costs and carbon footprint.