Chapter 5
Carbon Footprint Analysis of Software Systems

P. Selvakumar
https://orcid.org/0000-0002-3650-4548
Department of Science and Humanities, Nehru Institute of Technology, Coimbatore, India

T. C. Manjunath
https://orcid.org/0000-0003-2545-9160
Rajarajeswari College of Engineering, India

Abhijeet Das
https://orcid.org/0000-0003-4599-5462
C.V. Raman Global University, Bhubaneswar, India

ABSTRACT

In recent years, the term "carbon footprint" has emerged as a critical metric in understanding and addressing the environmental impact of human activities. Broadly defined, a carbon footprint refers to the total amount of greenhouse gases (GHGs), primarily carbon dioxide (CO_2), emitted directly or indirectly by an individual, organization, product, or activity, expressed in equivalent tons of CO_2. This measure includes emissions produced by burning fossil fuels for energy, transportation, manufacturing, and other industrial processes. The concept has gained increasing prominence as the global community intensifies efforts to combat climate change and reduce the accumulation of greenhouse gases that contribute to global warming and its associated adverse effects such as rising sea levels, extreme weather

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events, and biodiversity loss. Traditionally, discussions on carbon footprints have centered around sectors with visible and tangible environmental impacts—such as transportation, agriculture, manufacturing, and energy production.

INTRODUCTION TO CARBON FOOTPRINT

In recent years, the term "carbon footprint" has emerged as a critical metric in understanding and addressing the environmental impact of human activities. Broadly defined, a carbon footprint refers to the total amount of greenhouse gases (GHGs), primarily carbon dioxide (CO_2), emitted directly or indirectly by an individual, organization, product, or activity, expressed in equivalent tons of CO_2. This measure includes emissions produced by burning fossil fuels for energy, transportation, manufacturing, and other industrial processes. The concept has gained increasing prominence as the global community intensifies efforts to combat climate change and reduce the accumulation of greenhouse gases that contribute to global warming and its associated adverse effects such as rising sea levels, extreme weather events, and biodiversity loss. Traditionally, discussions on carbon footprints have centered around sectors with visible and tangible environmental impacts—such as transportation, agriculture, manufacturing, and energy production. However, with the rapid advancement and integration of digital technologies in every facet of life, a growing concern has surfaced regarding the environmental footprint of software systems and digital infrastructures. While software itself may appear intangible and invisible compared to physical industries, the underlying hardware, data centers, and energy consumption associated with running software applications have a significant carbon footprint. This growing realization has prompted researchers, developers, and policymakers to investigate the environmental consequences of software development, deployment, and usage, highlighting the need for sustainable practices within the software industry. Software systems, encompassing everything from mobile apps and websites to large-scale cloud computing platforms and artificial intelligence models, rely heavily on data centers and network infrastructure that consume vast amounts of electricity.

Moreover, the software development lifecycle itself can contribute to carbon emissions through the consumption of computational resources during coding, testing, debugging, and deployment processes. For example, automated testing frameworks, continuous integration/continuous deployment (CI/CD) pipelines, and extensive use of cloud-based development tools require substantial compute power. The rise of computationally intensive applications such as machine learning, big data analytics, and blockchain further exacerbates this trend, as these technologies demand significant processing power and storage capacity. These activities cumulatively increase