The Emerging Horizon of Information Technology in the Quantum Computational Landscape: A Preliminary Analysis

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Categoria do Trabalho

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Introdução

The rise of quantum computing represents a transformative shift in information technology, offering unprecedented computational capabilities grounded in principles of quantum mechanics such as superposition and entanglement. Recent advances have spurred global investment and interdisciplinary collaboration, especially concerning its potential for sustainable development. With increasing energy demands from classical high-performance computing infrastructures, the promise of a ``green quantum advantage'' — wherein quantum systems outperform classical counterparts in energy efficiency — gains strategic relevance. This study addresses the evolving interface between quantum computation and sustainable IT, exploring how quantum technologies may contribute to ecological responsibility and reduced environmental impact in data-intensive domains.

Objetivo

This study aims to analyze the intersection of quantum computing and sustainable information technology by identifying preliminary indicators of energy-efficient quantum advantages and evaluating their implications for environmental sustainability.

Material e Métodos

The research is grounded in a literature-based exploratory analysis using systematic review principles. Methodologically, the study synthesizes insights from peer-reviewed articles, workshop reports, and scientometric evaluations on quantum computing, with emphasis on green computing metrics and sustainability applications.

Core references include Jaschke & Montangero (2023) on the green quantum advantage threshold, Sood & Chauhan (2024) on the scientometric mapping of sustainability research in quantum computing, and the NSF Quantum for Climate workshop (2023), which outlines interdisciplinary priorities. A qualitative framework was used to classify quantum applications by relevance to environmental goals (e.g., energy system optimization, climate modeling), with cross-reference validation through co-citation patterns and algorithm performance metrics.

Resultados e Discussão

Findings suggest that while quantum computing has not yet reached full-scale energy efficiency superiority over classical architectures, the threshold for green quantum advantage is attainable in select use cases. Hybrid quantum-classical approaches and tensor network simulations reveal that entanglement complexity and gate fidelity are key factors in energy efficiency. Sustainable applications, such as climate forecasting and energy grid optimization, emerged as promising domains. Scientometric trends show increased global collaboration and investment in quantum solutions aligned with climate priorities. However, current NISQ-era limitations necessitate algorithm co-design and resource-aware modeling. The convergence of green IT and quantum R&D signals a growing shift in priorities toward ecologically responsible innovation in high-performance computing.

Conclusão

Quantum computing stands at the frontier of sustainable technological innovation. Though full realization of green quantum advantage remains dependent on hardware scalability and algorithmic maturity, early findings highlight its promise in energy-efficient computation. As interdisciplinary frameworks and funding structures evolve, quantum IT may become a cornerstone in the global transition toward sustainability.

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