

Green Manufacturing: Confronting Anthropogenic Pressures Transdisciplinary Insights, Policy Synergy, and Future-Oriented Research Frontiers

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Abstract

Green manufacturing has developed from a theoretical buzzword to an essential framework for viable industrial development. In the 21st century, industries face rising pressures due to resource scarcity, environmental crises, and growing societal exigencies for accountability. Manufacturing alone consumes approximately one-third of global energy and subsidize more than one-fifth of CO₂ emissions. The central summons to contest is no longer whether sustainability should be interspersed into industrial systems, but rather how this integration can be achieved effectively. This paper reviews global trends in green manufacturing, with insistence on circular materials, energy efficiency, digitalization over Industry 4.0, policy groundwork, and life-cycle assessment (LCA). The discussion also highlights key obstacles such as collapsed regulations, irregular data standards, and high employment costs, while exploring emerging opportunities in Industry 5.0 and digital LCA tools. By synthesizing 41 peer-reviewed and high-quality sources, this study identifies research directions and proposes a roadmap for aligning industrial growth with environmental sustainability.

Keywords

Green manufacturing, sustainability, circular economy, Industry 4.0, decarbonization, life-cycle assessment, industrial policy.