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Life Cycle Assessment of Wind Power Systems: A Comparative Analysis Across Different Climatic Regions

As the global energy landscape shifts toward sustainability, wind power has emerged as one of the most promising renewable energy sources due to its low operational emissions and abundant availability. However, despite its environmental benefits, wind power systems are not entirely impact-free throughout their lifecycle. Conducting a comprehensive Life Cycle Assessment (LCA) is therefore essential to understand the total environmental burden associated with wind energy technologies.

LCA is a methodological framework that evaluates the environmental impacts of a product or system throughout its entire life cycle, from raw material extraction, manufacturing, and transportation to operation, maintenance, and end-of-life disposal. In the context of wind power, LCA enables the quantification of environmental loads associated with turbine production, installation, operation, and decommissioning. Notably, factors such as wind resource variability, operational conditions, and maintenance requirements differ across climatic regions and can significantly influence a system's environmental performance.

This study aims to conduct a comparative LCA of wind power systems deployed in various climatic zones, including arid, temperate, and maritime regions. By highlighting the influence of climate on the environmental efficiency of wind systems, the findings will provide valuable insights for site selection, technological improvement, and policy development, ultimately supporting the sustainable expansion of wind energy worldwide.