A-160

Bridging the Gap in MDI Value Chains: A Dual-Metric Evaluation of Circularity and Carbon Footprint from CO Production to MDI Synthesis

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Carbon Monoxide (CO) serves as the foundational building block for a vast array of high-value chemicals, most notably Methylene Diphenyl Diisocyanate (MDI), the essential precursor for the polyurethane industry. As the chemical sector faces increasing pressure to defossilize, the reliance on Carbon Footprint (CFP) as the sole sustainability indicator is being challenged. This research introduces a comprehensive framework that integrates a dedicated inhouse Circularity Metric alongside traditional CFP to provide a more nuanced understanding of resource management and climate impact.

The study evaluates the sustainability profile of the CO-to-MDI value chain by examining various feedstock pathways, including fossil, biogenic and recycled carbon. By utilizing a simplified in-house carbon circularity matrix, we analyze the sustainability benefits from the initial CO production stage through to the MDI intermediate. This dual-metric approach allows for the identification of "circularity-positive" pathways that may be obscured when viewing the process through a solely emission based lens.

Our findings demonstrate that while CFP identifies the immediate climate impact, the circularity metric reveals the long-term strategic value of keeping carbon within the industrial technosphere. By stopping the analysis at critical gates, such as CO production, and then extending it to complex intermediates like MDI, this research provides a strategic roadmap for the chemical and polymer industries. The resulting framework enables decision makers to prioritize technologies that offer the best balance between greenhouse gas reduction and material loop closure, ensuring a resilient transition toward a circular economy.