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Greenhouse Gas Accounting & Hotspots Identification: A Perspective from the Microbial Fermentation Industry

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Abstract

Fermentation-based manufacturing processes, widely used in the production of food ingredients, beverages, enzymes, bio-based chemicals, pharmaceuticals, and alternative proteins, generate greenhouse gas (GHG) emissions from both direct operations and upstream/downstream value-chain activities. In addition to fossil-carbon-related emissions, these processes release biogenic carbon dioxide during fermentation, which forms part of the short-term biogenic carbon cycle. This study presents a comprehensive assessment of GHG emissions from fermentation industries operating in OECD countries, covering Scope 1, Scope 2, and Scope 3 emissions in accordance with the Greenhouse Gas Protocol. The accounting approach was refined through a double materiality assessment conducted across twelve global fermentation facilities manufacturing similar microbial products and derivatives. Primary data were collected from site-specific activity records and operational inventories, while secondary data were obtained from three internationally recognized emissions and life-cycle databases, principally for Scope 3 calculations. The analysis covers the period 2022–2024 and evaluates the distribution and evolution of emissions across different sites within a harmonized system boundary. Results indicate that supply-chain emissions (Scope 3) are the largest contributors to overall greenhouse gas emissions, followed by direct operational emissions associated with fossil fuel use. The study further demonstrates that regional electricity grid mixes, emission factor selection, and raw material sourcing strategies can significantly influence carbon footprint outcomes. These findings highlight key emission hotspots and provide valuable insights for scenario analysis, supporting data-driven decision-making and the transition toward lower-carbon fermentation-based manufacturing systems.

Keywords: Carbon Footprint; Climate Change; Fossil Carbon; Energy Management; Supply Chain