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Advancing Sustainable Energy: Prospects of Bio-Methanol and E-Methanol from Sewage Sludge and Solid Wastes

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Addressing the challenge of sustainable and renewable energy has spurred interest in bio- and e-methanol production from unconventional feedstocks, including sewage sludge and municipal solid wastes (MSWs) [1]. These sources, often considered environmental burdens, possess enormous potential to meet global energy demands while reducing greenhouse gas emissions [2].

Sewage sludge and MSWs serve as rich and high-quality sources of biodegradable organic matter and carbon for bio-methanol production [3]. These wastes can be gasified to yield syngas (a mixture of carbon monoxide, hydrogen, and carbon dioxide), which is subsequently catalyzed to form methanol. Moreover, biogas, produced during anaerobic digestion, can be reformed into syngas for methanol synthesis [4]. Under optimized conditions, these processes can achieve a thermal efficiency exceeding 60%, depending on feedstock composition and technology integration.

E-methanol production, on the other hand, integrates renewable hydrogen generated through water electrolysis powered by solar or wind energy. Carbon dioxide sourced from off-gases during sewage sludge incineration or anaerobic digestion can be utilized in e-methanol synthesis. Life cycle assessments indicate that carbon neutrality is achievable for e-methanol production using renewable energy sources. This approach significantly reduces the environmental footprint and enables the production of a high-value, renewable fuel from waste emissions.

The application of these technologies extends beyond electricity production. Utilizing waste streams for methanol generation addresses critical waste management challenges, reduces landfill dependency, and minimizes methane emissions from improperly disposed waste. Furthermore, transitioning from traditional fossil methanol to bio- and e-methanol could substantially lower carbon emissions in industries such as transportation and chemicals, thereby supporting global climate goals.

Despite these advantages, several challenges remain. Sewage sludge and MSWs are heterogeneous feedstocks, posing technical difficulties in preprocessing and gasification. In addition, the investment and operational costs of advanced waste-to-methanol plants are high,

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necessitating government support and active private sector participation. The scalability of these technologies depends on innovations in engineering, sound economic models, and the implementation of appropriate policies.

Integrating bio-methanol and e-methanol production into waste management systems represents a transformative opportunity for sustainability. By combining waste valorization with renewable energy and carbon recycling, these processes contribute to a circular economy framework. Greater attention from researchers, policymakers, and industry stakeholders is essential to unlocking the full potential of these promising developments.

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