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Co-production of biochar and electricity from oil palm wastes for carbon dioxide mitigation in Malaysia

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ABSTRACT

Power and heat production is the leading cause of greenhouse gas emissions in Malaysia, contributing to over 30% of total emissions. The transition from fossil to biomass resources in the power industry is an essential step towards achieving carbon neutrality in Malaysia. Oil palm wastes are the most abundant biomass resources in Malaysia because of the thriving oil palm industry. Consequently, two scenarios: (1) co-production of biochar and electricity, and (2) electricity generation, were proposed and simulated in Aspen Plus. A comprehensive evaluation system for mass and energy balances, techno-economic analysis, and life-cycle assessment was established to assess the two scenarios quantitatively. The results indicated that Scenario 1 achieved better economic and environmental benefits, the payback period was 6.12 to 8.89 years, and the global warming potential ranged from −885.23 to −1311.95 kg CO_2-eq/t. The state-level spatiotemporal trajectory of oil palm waste resources and CO_2 emission reduction potentials and economic benefits were analyzed. Theoretically, fully utilizing oil palm wastes in Scenario 1 would create economic benefits of 35.36 billion USD and mitigate CO_2 emissions by 131.97 million tons in 2021. This study provides useful guidance for exploiting oil palm wastes to achieve carbon neutrality in Malaysia.

1. Introduction

Malaysia is one of the largest oil producers in the Asia-Pacific region, and its fossil fuel resources have historically been seen as a source of economic growth and development. Its energy mix is heavily skewed towards fossil fuels, with coal, oil, and natural gas accounting for the vast majority of energy production and consumption. It is reported that more than 94% of energy consumption in 2019 came from fossil fuels, releasing 254.48 million tons of CO_2 (Data, 2022). Meanwhile, the sector of electricity and heat was the main contributor, with emissions of 130.03 million tons of CO_2 and an upward trend. A shift from fossil to biomass resources can decouple electricity and heat production from fossil resources and mitigate the resulting CO_2 emissions (Liao et al., 2020). Unlike fossil fuels, CO_2 emissions from the combustion of biomass or biomass-derived products are biogenic, meaning that carbon in the product comes from atmospheric CO_2 sequestered during photosynthesis. Thus, the mass application of biomass as bioenergy brings a new twist to the climate change trend (Liu et al., 2022).

Malaysia is endowed with abundant biomass resources because of its unique tropical and humid climate, generating about 168 million tons of biomass annually, of which oil palm wastes (OPWs) are the most abundant biomass resources because of the thriving oil palm industry (Ameen et al., 2022). Over 124 million tons of solid OPWs were generated from palm oil mills or oil palm plantations in 2021. The total energy potential of OPWs (2.55 EJ) is equivalent to 61.74% of primary energy consumption (4.19 EJ) in Malaysia in 2021 (Statista, 2023). Currently, mesocarp fiber (MF) and palm kernel shell (PKS) have been extensively utilized as boiler fuels in combined heat and power systems to provide electricity for the operation of palm oil mills; low energy

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