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Assessment of Biochar Production and Integration into HIsarna Ironmaking

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HIsarna ironmaking is a breakthrough smelting-reduction technology with the potential to reduce CO_2 emissions by about 50% when operated with coal. However, further decarbonisation of the process requires replacing fossil carbon with sustainable alternatives. In this context, biochar derived from woody biomass emerges as a promising renewable carbon carrier, provided it can be produced economically within the plant boundary. This study evaluates biochar integration to the HIsarna process operations from the perspective of raw material consumption, unit wise energy requirements, and by-product utilisation using a flowsheet modelling approach. In the present study, biochar is produced by slow pyrolysis of pinewood biomass with moisture contents of 33% and 10%, resulting in yields of approximately 35% biochar, 50% bio-oil, and 15% biogas. The analysis explicitly accounts for energy demand associated with drying, pyrolysis, and grinding, and for the utilisation of bio-oil and biogas either through internal combustion or through a combined strategy of bio-oil selling and biogas burning. Four cases are analysed by combining two biomass feedstocks (raw pinewood biomass and torrefied biomass) with two heating options for the pyrolysis unit (natural gas fired heating and electric heating). The flowsheet modelling is designed to supply the biochar required for a HIsarna plant producing 1 million tonnes of hot metal per year. Mass and energy balances are established for the integrated system, followed by a techno-economic evaluation of the net biochar supply cost to HIsarna process. The analysis is carried out assuming representative baseline values for biomass price, electricity price, and carbon credits. Under these base-case conditions, Case1, the bio-oil and biogas burning pathway delivers a net energy surplus of about 8 GJ/t to 13 GJ/t biochar produced, with the resulting net biochar supply cost showing a strong dependence on biomass type and heating option. In contrast, Case 2, the bio-oil selling with biogas burning pathway reduces the net energy surplus to approximately 1 GJ/t to 5 GJ/t biochar produced but improves the net biochar supply cost compared to Case 1. Sensitivity analysis indicates that increasing electricity prices penalise electrically heated configurations most and shifts the preference toward natural gas based pyrolysis.

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