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A life cycle framework for rare earth element recovery from coal ash

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Coal fly ash waste is a potential source of alkalinity for CO_2 mineralization as well as rare earth elements (REE) and supplementary cementitious materials (SCM). We present a holistic, transparent life cycle assessment model of coal ash as a feedstock for indirect carbon mineralization allowing for the tracking of energy and material inputs and outputs with a cradle-to-gate system boundary. We analyze the carbon storage and coproduct (REE and SCM) recovery potential of high and low carbon storage potential coal ashes. The model allows for the variation of grid carbon intensity; ash feedstock elemental composition, particle size distribution and moisture content; CO_2 source and associated separation and compression energy; extent of reagent electrochemical regeneration; and ash transport distance. We find three plausible scenarios to achieve net CO_2 removal with coal ash mineralization: (1) high efficiency reagent regeneration with a clean power system, (2) feedstock constrained deployment with coproduct displacement via avoided emissions burden, and (3) reduced chemical intensity, sacrificing some mineral revenue for lower energy and reagent use.